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THE JOURNAL OF WILDLIFE MANAGEMENT

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APRIL - 1954
Vol. 18 No. 2

CONTENTS

Training for Wildlife Management ..... *Robert A. McCabe* 145

Fish Movement in Irrigation Diversions ..... *William D. Clothier* 150

Value of Waterfowl Refuges in Illinois ..... *Frank C. Bellrose* 160

Planning Wildlife Experiments Involving Percentages ..... *David E. Davis and Calvin Zippin* 170

Pheasant Winter Roosting Cover Preference ..... *L. Jack Lyon* 179

Status of Beaver in West Virginia ..... *R. Wayne Bailey* 184

Apparatus for Study of Incubated Bird Eggs ..... *Harold C. Hanson* 191

Mink and Otter as Muskrat Predators ..... *Kenneth A. Wilson* 199

Smallmouth Bass Stocked in a Warm-water Stream. *R. Weldon Larimore* 207

Ecology of Marsh Raccoons ..... *Robert S. Dorney* 217

Food Relations of the Least Chub .. *Robert C. Pendleton and Earl W. Smart* 226

Trout Populations and Cover on a Small Stream .... *Marvin F. Boussu* 229

Age in Acquisition of Parasites by Canada Geese ..... *Everett E. Wehr and Carlton M. Herman* 239

Carp Destruction of Aquatic Vegetation ..... *C. W. Threinen and Wm. T. Helm* 247

Effect of Carp Exclosures on Aquatic Vegetation .... *C. A. Tryon, Jr.* 251

Daily Patterns of Pheasant Hunting Pressure ... *Charles E. Friley, Jr.* 255

Analysis of Woodcock Singing Ground Counts ..... *E. L. Kozicky, T. A. Bancroft and P. G. Homeyer* 259

Available Browse Following Aspen Logging ..... *Casey E. Westell, Jr.* 266

Reviews 272

Recent Publications 278

Briefer Articles—A field observation method of aging broods of wood ducks, by Robert E. Dreis; An automatic live-trap for raptorial birds, by Harrison B. Tordoff; Food habits of Pennsylvania house cats, by Thomas Eberhard; Comparisons of small fish populations in Pymatuning Lake, Pennsylvania, by F. J. Schwartz and C. A. Tryon, Jr. 280

The Journal of Wildlife Management is printed by the Cayuga Press, Inc., and published by The Wildlife Society in January, April, July and October, at 113 East Green St., Ithaca, N. Y. Subscription $5.00 per year and current numbers $1.25. Society members cover subscription in annual dues. Back issues are available; volumes 1 through 8, and 13 at $8; 9 through 12, and others since 1949 at $6 per volume, $1.50 per issue.

Manuscripts for publication, books and papers for review, news notes and correspondence concerning them should be sent to the *Editor*, Oliver H. Hewitt, Department of Conservation, Cornell University, Ithaca, N. Y.

Dues, subscriptions, changes of address, requests for missing numbers, applications for membership, and other correspondence should be sent to the *Executive Secretary*, D. L. Leedy, Branch of Wildlife Research, U. S. Fish and Wildlife Service, Washington 25, D. C.

The Society is not responsible for supplying missing issues unless the Executive Secretary is notified within 60 days of the date of publication.

Entered as Second Class Matter, at the Post Office at Ithaca, New York, June 18, 1951, under the Act of March 3, 1879.

Articles in this Journal are indexed in the Agricultural Index, available in many libraries.

THE JOURNAL OF WILDLIFE MANAGEMENT

VOLUME 18 APRIL, 1954 NUMBER 2

TRAINING FOR WILDLIFE MANAGEMENT

Robert A. McCabe

Department of Wildlife Management, University of Wisconsin, Madison

There is no definition of wildlife management in any dictionary. Before defining this term, I would like to present what I feel is pertinent background.

Wildlife management, from its inception in antiquity to the involved procedures of present-day English game keepers, has been considered an art.

When at long last our American wildlife resources were dangerously depleted, we attempted to correct the situation in short order. The need was genuine; the haste was doubtless prompted by a feeling of guilt and shame. Our efforts were channeled to parroting European game methods, and in this mimicry we were attempting to be artisans. The centuries of practice and experience necessary to mellow and mature the European art of wildlife management were denied the American management task, and as a result we failed. The wildlife literature of the 1930's is strewn with wreckage of management programs. Fortunately the urgency allowed little time for wringing of hands or wailing in the night. The single common denominator of most of our failures was that we did not understand our land and animals, or the relationship between them.

It is impossible to say where or when the rude awakening took place. This fact, however, stands out: American wildlife management, to become a functioning entity, had to metamorphose from an art into a science.

* * * *

In the metamorphosis, the first cracking of the rigid integument of nonscientific management came in 1933 with Aldo Leopold's book, GAME MANAGEMENT.

Although at that time he defined wildlife management as an art, no other factor was more effective in the conversion of this field from an art to a science than was the pen of Aldo Leopold.

In the last paper he wrote before his untimely death in 1948, was the statement: "It is an axiom in science that it is futile to attempt the practical in advance of the fundamental, because premature practicality ends in a blind alley." The lack of understanding of our wildlife that leads us into a blind alley, and the prerequisite need for fundamentals, switched the emphasis from management to research.

Wildlife research for the most part gravitated to academic surroundings where taxonomy, physiology, parasitology, chemistry, endocrinology, and a dozen other plant and animal sciences, plus geology, soils and meteorology, dealing with inorganic aspects of the environment, formed the foundation on which

the research was built. Thus wildlife research born of many sciences is claimed by none — nevertheless a profound change has occurred since the days of inadequate artisans. The scientific strivings of this newly unfolding field are exemplified in the words of Paul L. Errington: "Wildlife research is scientific in nature and must be sufficiently well done to hold together when subjected to scientific criticism."

Wildlife research can be observational, analytical or experimental, but facts thus obtained can benefit animals or environment only when they clarify the relationships between the two. The die so cast led inevitably into the field of ecology. Here the old art of wildlife management emerged as the science of wildlife ecology.

This does not presuppose that a knowledge of species ecology will produce sound management. It does mean that a knowledge of wildlife ecology is the best basis on which to found an active management program.

* * * *

What I have just related is an abbreviated version of a change as subtle and forceful as the bursting of a bud and about as reversible. I would now like to redefine wildlife management as "the scientific manipulation of land, plants and/or animals in the best interests of the entire biota." This definition implies: (1) that land also includes all water resources, (2) "animals" includes man without infringement on his personal liberties, and (3) that on occasion the best management may mean complete abstinence from manipulation.

We continue traditionally to maintain the word management in many instances when we mean ecology. The wildlife ecologist is a manager only in the way in which he applies his training.

This definition and clarification is necessary because training in wildlife management is predicated on the fact that we are training scientists, not artisans.

The training of a wildlife ecologist must include two types of emphasis: first, the knowledge and resultant skills acquired from academic training; and second, the understanding and acquisition of an ethical code and sense of esthetic values toward conservation as a whole.

Of the two, the latter is more difficult to instill, because these attitudes are largely self-taught. It is this aspect of dealing with things in nature that is more nearly akin to religion and hence extremely personal. The teachers of wildlife ecology should, through subject matter in courses and through field experience, create the media in which the student himself will build a sound wildlife philosophy. I wish I could give a formula or set of rules by which this end could be accomplished, but this is impossible because there is none. The greatest wildlife teacher I ever knew taught these attitudes by example. No one fortunate enough to come under the influence of Aldo Leopold could fail to understand and appreciate the need for a high code of morality toward wild things. There may be other ways to teach this philosophy: more power to them. Whatever form of pedagogy is used, it should be sufficiently impressive in its appeal to the heart and mind of the student so that the results are profound and lasting.

There are three fundamental attitudes that I feel are essential to training

in wildlife management. These may be acquired slowly through self-education or they may be learned in school. Ultimately, however, they must become the intellectual core of the wildlife scientist.

The first is the realization that animals as well as plants have their roots in the soil, and again that man is not exempt from this rootage. Here, too, must be the realization that soil is not just dirt but the vital, life-giving substance that is the bone and body of our country. More to the point is that the good earth has a "soul" as well, capable of being loved, and like a small child responding to the care which arises from such affection.

Our society has all sorts of laws and rules dealing with the misuse or abuse of trees and the forest. We abhorred and looked with disdain on the "cut out and get out" practice of the lumber barons in the 1800's. We are unmoved by the "deplete and abandon" land-use as of 1954.

When the hair on the back of one's neck rises in disgust and indignation at the sight of an eroding gully, of a swollen cocoa-colored stream, or plow furrows paralleling a steep slope, then a high order of professional ethics has been achieved.

Second, the awareness that in wild places and wild things there can be seen a pattern of harmony and balance that must be preserved. Our "nothing to worry about" frame of mind considers our obligations to posterity in terms of park statuary. The natural world is a series of biological systems within a larger biological system. Tampering or removing one of even the smallest parts may jam the larger gears. The starling that fouls our city streets and the carp that muddies our lakes are the results of tampering. The removal of the water-holding blanket of grass (turned under by the plow or worn away by too many bovine teeth) has created a dust bowl and a need for federal subsidy. The conviction that economic expedient does not always justify the upsetting of biotic balance typifies this second attitude.

Third, the belief that conservation includes the wise use of our resources. Failure to reduce deer herds in many states results in a loss of both deer and forests. Such flagrant misuse of resources is caused by an emotional blindness to obvious remedial action. Encroachments by the Reclamation Service and Army Engineers on national parks, wilderness and wildlife habitat are the result of a distorted sense of values. The attempt by a few powerful western stock men to legalize the use of public lands for personal gain needs little comment. These are the cankers of misuse of natural resources about which we must form an opinion.

I read recently a paper on conservation education. The author, among other things, accuses the professional conservationist of a "bemoaning of the past, feeling sorry for the passenger pigeon, the auk, and the buffalo." He goes on to say, "Certainly it would be nice to have buffalo roaming southern Wisconsin today as they did in the past, but I think that the country needs the milk and other farm products far more." The author is right: there is much bemoaning, not however out of pity for these animals so ruthlessly extirpated, but because the lessons they taught in the misuse of a natural resource have not yet been learned, or as in the paper

just mentioned, not yet recognized.

In our economically minded society the *use* of a commercially important resource will gain ready acceptance. Its *wise use* may have to be fought for, often by those who stand to gain nothing personally. The willingness to fight on principle for wise utilization of our natural resources indicates a maturing of this third attitude.

* * * *

I discussed wildlife philosophy first because on it depends the way and the degree to which an education is used.

There are many academic programs for training wildlife ecologists, almost as many as there are schools with a wildlife curriculum. Time does not permit a comparative study of wildlife training in American schools—even if I had the data, which I do not.

What follows relative to training in wildlife management is wrought of limited experience but strong conviction.

Training in wildlife management can be acquired at three academic levels, the bachelor's, master's, and Ph.D. degree. I will not attempt to discuss the desirability or drawbacks of the bachelor's degree in wildlife management because I am able to uphold only the negative side of the argument.

At the master's and Ph.D. levels we must keep in mind that we are training scientists, more specifically, applied scientists. Before any science can be applied, it must first be understood. I feel that it is easier to proceed from the pure to the applied approach in science than vice versa.

The undergraduate program of the advanced student in wildlife management should therefore contain, over and above the required cultural courses in the social sciences, a maximum of subjects in the basic sciences of zoology, botany, chemistry, mathematics, etc. From such a base can be built a more complete understanding and a greater facility for applying the principles of wildlife management. It would be difficult to overestimate the importance of speaking and writing at any educational level, particularly in conservation, and specifically in wildlife management. Individual expression and the training that teaches it are only slightly less important than the science training that produces the scientist.

The classroom and field program of the graduate student should be tailored to his personal aptitudes and needs. Research for the master's degree must be a problem worthy of at least two years' work, must be competently pursued so as to make a contribution to the field and written sufficiently well to be accepted for publication. The term-paper type of master's degree research hurts the student, the school and faculty who condone it, and the field of wildlife management. We cannot afford to give academic degrees on pleasing personalities or good intentions any more than we can expect to mass produce game managers.

A student completing a master's degree from a strong background of basic science is in the best position to carry on research or undertake a management program anywhere.

* * * *

The Ph.D. candidate in wildlife management, Dr. Rudolph Bennitt said, "Should perform the most original, fundamental and highly technical work of which he is capable, leaving purely descriptive research largely to others."

To this, I can add only "Amen." It becomes the responsibility of the educational institution to see that the men accepted possess the greatest capabilities. The Ph.D. candidate attempts to make a major contribution to knowledge in the field of wildlife management. In so doing, he undertakes extensive research, usually of a fundamental nature. It is in this research that he must bring all his accumulated knowledge to bear on the problem at hand. His results, which are usually forthcoming in not less than two years beyond his master's degree, must be commensurate with the intellectual effort, and as in the case of the master's degree, be deserving of publication.

It is impossible to set specific standards for doctorate training because each case is unique in its major aspects. The thread of commonness in all doctorate research, unfortunately, is personal economic privation. Generally, the approach to Ph.D. caliber research should be as follows: (1) the planning—astute, (2) the pursual—untiring and unbiased, and (3) the presentation—simple and scholarly.

No guarantee can be made that the possessor of a sheepskin will be able to cope with all the situations to come his way, or that he is the best man for a given job. The least that can be said is that the chances of his succeeding are proportional to his training.

* * * *

The foregoing may be an oversimplified mapping of a trail with many forks. It goes without saying, however, that education and sound philosophy are necessary to the making of a well-trained wildlife ecologist. It is equally important that the student possess a pleasing personality, strong physique, and ingenuity to handle himself creditably in the field, office, or classroom. His education should have awakened an unbiased inquiring mind—a trait commonly referred to as the "scientific attitude."

The ideally trained student in respect to background, education, and intellectual flexibility may never be attained, but it should not be for lack of persistent effort. Training in wildlife management must produce a thinker, a doer, and a leader in each student—the public interest requires it and our profession demands it!

Accepted for publication October 15, 1953.

EFFECT OF WATER REDUCTIONS ON FISH MOVEMENT IN IRRIGATION DIVERSIONS[1]

William D. Clothier

Fishery Research Division, Woonsocket, South Dakota

Data collected from the Low Line Canal during a study of irrigation fish loss and movement in Gallatin Valley, Montana, 1950–1951, showed a direct correlation between severe water reductions and the movement of 36.87 pounds of legal game fish back into the West Gallatin River (Clothier, 1952). This phenomenon has not been entirely overlooked with respect to saving fish lost in irrigation ditches. Dr. Richard B. Miller states, "There now exists a sort of agreement (in Alberta) whereby headgates are shut slowly." (Correspondence, November 24, 1951). For several years in the present study area, the volume of flow in the Kleinschmidt Canal has been decreased a few days before headgate closure solely to stimulate fish to return to the river. Despite the general recognition that water reductions save fish, little quantitative information is available.

To verify and enlarge upon previous findings, four West Gallatin River canals (Middle Creek Supply, Farmers, Kleinschmidt and Spain-Ferris) were studied in 1952. A series of 500-foot sections within approximately one mile behind the headgate of each canal were qualitatively sampled during the regular irrigation season with a "shocker" powered by a 500-watt alternating-current generator. Trout, whitefish, and suckers were weighed, measured, marked by distinctive fin-clips, and returned to the water within the sections where found. There were two marking periods in two of the canals, the first in connection with a related study.

Three days prior to headgate closure at the end of the irrigation season, the volume of flow in the Middle Creek Supply, Farmers, and Kleinschmidt Canals was reduced abruptly to the lowest level capable of supporting fish movement. The Spain-Ferris Canal served as a control. Its water supply was turned off without a preliminary period of decreased flow.

Each 300-foot section of all canals from the headgates downstream to the last section in which fish were marked was blocked by nets and shocked after the water was turned off. Distances traveled by marked fish were measured with a 100-foot steel tape.

Middle Creek Supply Canal (decreed right 76.2 c.f.s.)

Fish from four 500-foot sections of the Middle Creek Supply Canal were marked and released (Table 1) on August 20 several days after the volume of flow had been reduced to 41.9 c.f.s.

[1] A contribution from Dingell-Johnson Investigations, Project F-3-R, Montana State Fish and Game Department. Thanks are extended to Don C. Quimby, who read and made suggestions for improving the manuscript. Considerable assistance in the field was given by John Spindler and Richard Graham, graduate students of Montana State College. Cooperation of participating Gallatin Valley Ditch Companies is appreciated.

TABLE 1.—TROUT AND WHITEFISH MARKED AND RELEASED IN THE MIDDLE CREEK SUPPLY CANAL

Species	Number	Weight (pounds)	Length in inches	
			Average	Range
Rainbow	58	20.24	8.8	6.2 - 15.1
Brook	19	4.96	7.7	3.4 - 14.4
Brown	12	11.68	12.1	3.3 - 18.7
Whitefish	8	0.75	4.6	3.4 - 11.9
Total	97	37.63		

TABLE 2.—NUMBERS AND WEIGHTS OF TROUT, WHITEFISH, AND SUCKERS TAKEN FROM THE 4900-FOOT STUDY SECTION OF THE MIDDLE CREEK SUPPLY CANAL

Species	Number	Weight (pounds)	Percentage composition	
			By number	By weight
Rainbow	249	39.35	46.4	47.9
Brook	126	11.97	23.4	14.6
Brown	58	24.50	10.8	29.8
Cutthroat	5	0.76	0.9	0.9
Whitefish	97	5.47	18.1	6.7
Suckers	2	0.09	0.4	0.1
Total	537	82.14	100.0	100.0

from decreed right. There were no further major water cuts until October 8 when flow was reduced to 7.7 c.f.s. This water flowed under the headgate through a space approximately 1–1/2 inches high. Within five minutes two eight-inch trout moved rapidly upstream to the headgate. The increased water pressure and the narrow opening possibly impeded fish movement out of the canal.

Rainbow trout was the most abundant game species in the 4900-foot study section following headgate closure on October 11 (Table 2). Eastern brook trout, brown trout, cutthroat trout, whitefish, and suckers comprised the remaining 53.6 per cent. Approximately 63.5 per cent of the trout and 79.4 per cent of the whitefish were less than seven inches in total length; the two longnose suckers less than six inches.

Fish concentrations were found behind the headgate and wherever brush, undercut banks, and pools furnished concealment. These areas of concentration were often small and widely separated, suggesting that the reduced flow had effected a redistribution of the population. There were 21.75 pounds of trout and 0.59 of a pound of whitefish found on a 15-foot cement ramp immediately behind the headgate. Only 1.04 pounds, all trout, were taken from the remaining 285 feet of this first section. Game fish poundage in Section 1 represented 28.5 per cent of the total pounds taken in the entire study area (Fig. 1).

About 11 per cent of the poundage (all trout) was taken from a shallow 20-foot pool in Section 2 near one bank under overhanging willows. Sections 3 to 5, inclusive, had few pounds of fish.

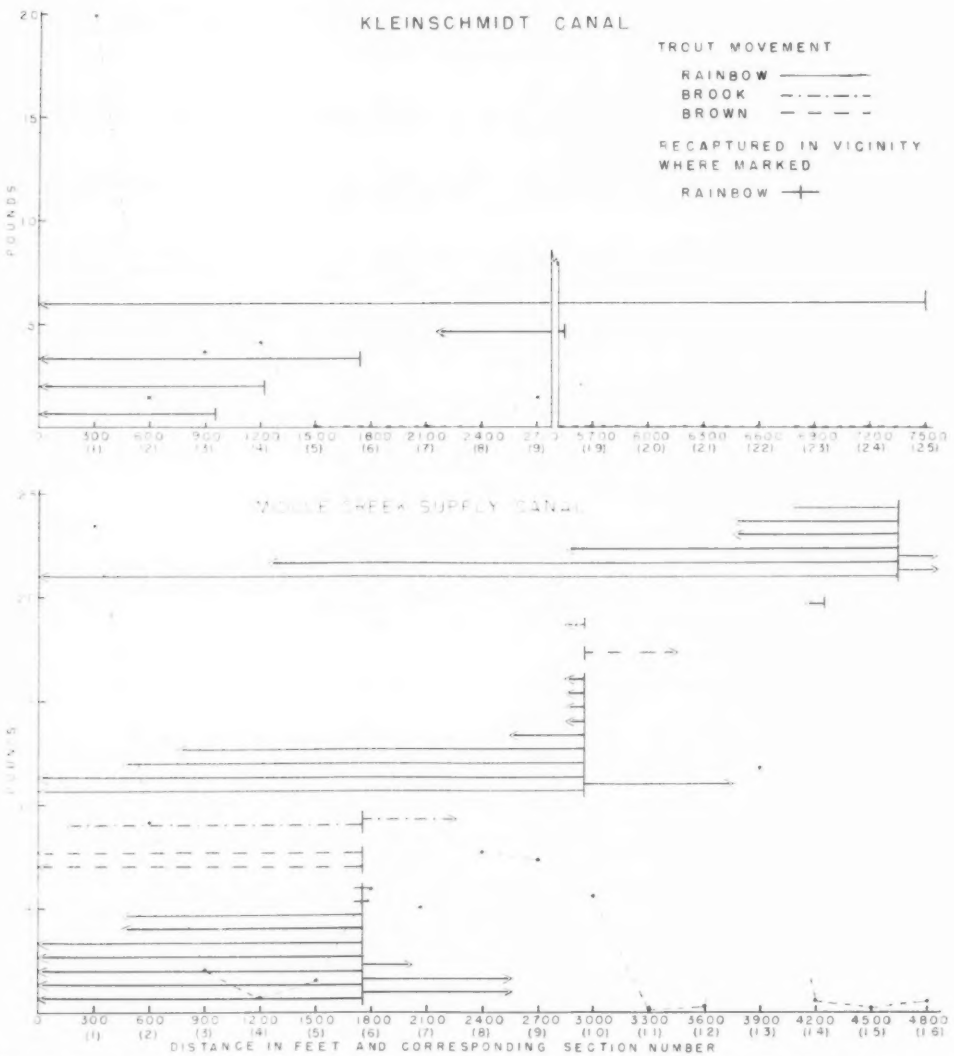

FIG. 1. Pounds of trout and whitefish taken in each 300-foot section of Kleinschmidt and Middle Creek Supply Canals (superimposed broken line), and direction and distance marked recoveries traveled from point of release (vertical bars). Zero feet at the headgate. Each symbol signifies an individual fish.

This area was characterized by rubble and very shallow water. A fairly uniform distribution of poundage (38.9 per cent of the total) was taken from Sections 6 through 10. This entire area was a continuous pool 12 to 18 inches deep. The water in Sections 11 through 16 was generally less than 10 inches deep. Few pounds were taken in this part of the ditch except in Section 13, which contained 11.84 pounds of game fish (14.4 per cent of total poundage captured).

Most of these were found in shallow water beneath a pile of leaves and brush accumulated on fence wires.

Approximately 41.6 per cent of 89 marked trout in the Middle Creek Supply Canal were recovered. None of the marked whitefish were retaken. Sixty-one days elapsed from date of marking to date of headgate closure.

Of the marked trout recovered, 73 per cent had moved upstream for distances ranging from 150 to 4850 feet (Fig. 1). Eight were found between 200 and 800 feet downstream from the point of release, and two were recovered in the area where marked. There was no distinct difference shown in direction of movement by individual species of marked trout.

Two marked trout less than seven inches in total length were recovered. One 4.3-inch brook trout found at the headgate had moved 1750 feet up the canal, and a 6.9-inch rainbow trout recovered some distance from the headgate had gone upstream 450 feet. The trout that traveled the greatest distance upstream was a 10.0-inch rainbow (Fig. 1).

Marked fish that did not reach the headgate were found in areas affording concealment suggesting that exposure resulting from water removal stimulated fish to seek cover. Perhaps they would travel longer distances if cover were not available. Exposure may stimulate fish to move more readily than does the actual process or amount of flow reduction. A few water reductions in the Keughen Canal during the 1950–1951 fish movement investigation equaled the present reduction in volume without stimulating an up-canal movement of fish into a weir. Only about half of the water was turned out of the Keughen Canal by these reductions leaving sufficient water depths for concealment.

KLEINSCHMIDT CANAL
(DECREED RIGHT 151.0 C.F.S.)

The Kleinschmidt Canal carried about 50.5 c.f.s. of water when fish were taken from the canal and marked August 5 and 17 (Table 3). Flow remained relatively constant from these dates until it was decreased abruptly to 13.3 c.f.s. October 14. All water was turned off October 17. A time lapse of 74 and 64 days occurred between the two dates of marking and headgate closure.

Excluding sculpins, rainbow trout and whitefish were the dominant species in the study area (Table 4). There were no cutthroat trout or suckers captured. Six of the 19 whitefish and 29 of the 59

TABLE 3.—TROUT AND WHITEFISH MARKED AND RELEASED IN THE KLEINSCHMIDT CANAL DURING TWO SHOCKING PERIODS (AUGUST 5 AND 17).

Species	Number	Weight (pounds)	Length in inches	
			Average	Range
Rainbow	18	5.71	8.4	4.6 - 13.9
Brook	1	0.41	10.3	.... - ....
Brown	2	0.41	7.9	7.8 - 8.0
Cutthroat	3	0.43	7.5	7.0 - 8.0
Whitefish	3	1.42	12.3	11.5 - 13.0
Total	27	8.38		

TABLE 4.—NUMBERS AND WEIGHTS OF TROUT AND WHITEFISH TAKEN FROM THE 7500-FOOT STUDY SECTION OF THE KLEINSCHMIDT CANAL

Species	Number	Weight (pounds)	Percentage composition By number	By weight
Rainbow	42	15.10	53.8	49.4
Brook	14	2.44	18.0	8.0
Brown	3	1.13	3.8	3.7
Whitefish	19	11.90	24.4	38.9
Total	78	30.57	100.0	100.0

trout taken were less than seven inches in total length.

Trout and whitefish located immediately behind the diversion headgate comprised 65.2 per cent of the total poundage taken in the entire study area (Fig. 1). These fish were concentrated similar to those taken at the Middle Creek Supply Canal headgate. The remaining 10.64 pounds of game fish taken from the Kleinschmidt Canal were divided among Sections 2, 3, 4 and 9, which were predominantly rubble and gravel with a few isolated areas of water three to six inches deep. Water depths throughout the remainder of the study area did not exceed 14 inches in depth. Sparse vegetative cover and a smooth channel bottom provided little concealment for fish in this lower area.

Of the fin-clipped trout, only five rainbow (20.8 per cent) were recovered (Fig. 1). Each had moved upstream for distances ranging from 950 to 7500 feet. All but one swam under the downstream headgate to reach the headgate at the canal intake. The smallest recaptured rainbow trout (5.5 inches in total length) traveled 950 feet. A 12.9-inch rainbow trout moved the maximum distance of 7500 feet.

No marked whitefish were retaken.

FARMERS CANAL
(DECREED RIGHT 268 C.F.S.)

Fish were marked (Table 5) and recovered on two occasions in the Farmers Canal. Trout marked in the 900 feet immediately behind the second headgate on August 4 totaled 28. This number

TABLE 5.—FISH MARKED AND RELEASED IN THE FARMERS CANAL DURING TWO MARKING PERIODS (AUGUST 4 AND 20)

Species	Number	Weight (pounds)	Length in inches Average	Range
Rainbow	38	15.81	9.5	4.6 - 14.0
Brook	84	17.08	7.6	2.7 - 12.0
Brown	7	8.10	13.0	7.5 - 20.2
Cutthroat	2	0.33	7.9	7.6 - 8.2
Whitefish	3	0.03	3.3	3.1 - 3.4
Suckers	9	15.97	16.5	7.7 - 19.8
Total	143	57.32		

was added to on August 20 when 103 trout, three fingerling whitefish and nine longnose suckers were fin-clipped and released in three additional sections (total length 1500 feet). The latter sections represented the area from the first headgate to 4800 feet downstream. Subsequent recoveries included 49.6 per cent of the trout, none of the whitefish, and 43.0 per cent of the suckers. The marked fish that traveled the greatest distance (4500 feet upstream) was a 7.3-inch eastern brook trout.

Volume of flow during the two marking periods was near 51 c.f.s. A gradual decrease to approximately eight c.f.s. occurred after the fish were marked and coincidental with the natural lowering of river level. This gradual reduction had not been anticipated, and by September 24 it appeared advisable to reshock the area behind and adjacent to the first headgate and the one immediately in front of the second headgate. Each area was a favorable fish habitat with water depths up to four feet. This water is constantly freshened by seepage from springs. Marked fish moving from other parts of the canal as a result of slowly diminished flow were likely to be retained in one of the two pools.

A few days subsequent to September 24, the ditch company adjusted the canal intake and increased volume of flow to 16.3 c.f.s. Arrangements were then made to have the water cut sharply three days before headgate closure as originally planned. Thus on October 10 the flow was reduced to 4.0 c.f.s., and completely turned off October 13. The second recovery shocking proceeded immediately after headgate closure, and included the entire area from the first headgate to 4800 feet downstream.

Eastern brook trout was the most abundant species taken during the two recovery periods (Table 6). All other species comprised 45.7 per cent of the total. Of 403 trout taken, 33.5 per cent were less than seven inches in total length. No adult whitefish were captured. Suckers ranged from 6.6 to 18.5 inches in total length, and mean length was 14.5 inches.

A total of 27.13 pounds of trout, 0.80 of a pound of whitefish and 6.25 pounds of suckers were taken in Sections 1, 2 and 3 behind the first headgate on September 24 (Fig. 2). There were 35.17 pounds of trout and 0.34 of a pound of whitefish removed from Section 8 in front of the second headgate. None of

TABLE 6.—NUMBERS AND WEIGHTS OF TROUT, WHITEFISH, AND SUCKERS TAKEN DURING TWO RECOVERY PERIODS FROM THE 4800-FOOT STUDY SECTION OF THE FARMERS CANAL

Species	Number	Weight (pounds)	Percentage composition By number	By weight
Rainbow	87	32.25	15.9	26.5
Brook	298	60.68	54.3	49.9
Brown	15	13.33	2.7	11.0
Cutthroat	3	1.36	0.5	1.1
Whitefish	139	3.21	25.3	2.6
Suckers	7	10.83	1.3	8.9
Total	549	121.66	100.0	100.0

the fish was returned to the canal, and all but suckers were transported to other waters.

There were 46 marked trout and two marked suckers taken during this first recovery period (Fig. 2). Most of these fish were found in the same two pools where fin-clipped, which suggests that gradually decreased flow had little effect on fish movement when deeper water afforded concealment. Seven of the trout marked in the shallow 900-foot area ad-

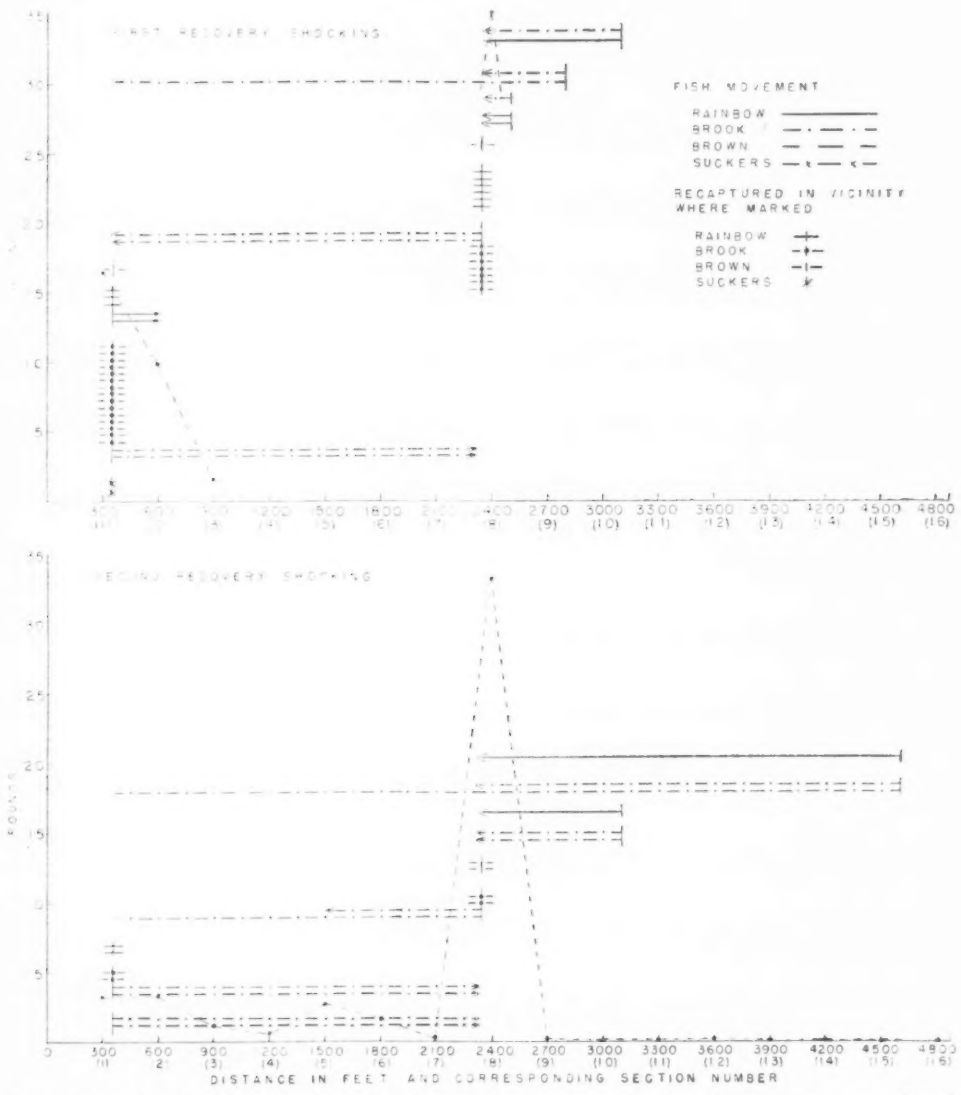

FIG. 2. Pounds of trout and whitefish taken during two recovery shockings in Farmers Canal (superimposed broken line), and direction and distance marked recoveries traveled from point of release (vertical bars). Zero feet at the headgate. Each symbol signifies an individual fish.

jacent and downstream from the second headgate had moved up the canal to one or the other protective pool in Sections 1, 2 and 8.

During the second recovery period, only 47.39 pounds of trout and whitefish were taken from the entire 4800-foot study area (Fig. 2). Almost 70.5 per cent of this poundage was found in the pool immediately in front of the second headgate (Section 8), which nearly equaled the amount previously removed from the same section. Less than a pound of trout and whitefish were found downstream in Sections 9 through 16, and these were all fingerlings.

Eighteen marked trout and two marked suckers were taken during this second recovery period (Fig. 2). All movement of fish marked downstream from the second headgate was in an up-canal direction. Apparently the sharp decrease in flow to 4.0 c.f.s. had a part in stimulating these fish to move upstream and contributed to the void in Section 8.

SPAIN-FERRIS CANAL
(DECREED RIGHT 121.3 C.F.S.)

Water in the Spain-Ferris Canal was turned off without a preliminary three-day period of reduced flow to establish whether many marked fish move in an up-canal direction despite a sharp water cut. Flow in this ditch diminished from 30.0 c.f.s. to 20.4 c.f.s. between the marking period and the water turn-off-date (September 12 to November 4). The time lapse between these two dates was 53 days. Actual censusing was begun November 6.

Within 15 minutes after headgate closure four brown trout, one rainbow trout, two small unidentified trout, and two adult whitefish responded to reduced flow by moving upstream to the headgate. The identified trout ranged in size from an estimated 1 to 2–1/2 pounds each. Probably these fish subsequently swam a short distance downstream to deeper water. About 1500 feet behind the headgate another trout (estimated length eight inches) was observed struggling upstream over a shallow riffle.

Whitefish was the most abundant game species taken in the 4200 feet adjacent and downstream from the headgate (Table 7). Brown trout comprised 56.9 per cent of the total number of trout captured. Longnose suckers were found in greater numbers than in any of the canals investigated. Game

TABLE 7.—NUMBERS AND WEIGHTS OF TROUT, WHITEFISH, AND SUCKERS TAKEN FROM THE 4200-FOOT STUDY SECTION OF THE SPAIN-FERRIS CANAL

Species	Number	Weight (pounds)	Percentage composition By number	By weight
Rainbow	67	30.91	6.6	6.8
Brook	43	14.19	4.2	3.1
Brown	174	101.60	17.0	22.5
Cutthroat	22	5.40	2.2	1.2
Whitefish	541	203.10	52.9	44.9
Suckers	175	97.37	17.1	21.5
Total	1022	452.57	100.0	100.0

fish less than seven inches in total length included 31.8 per cent of the whitefish and 5.2 per cent of the trout. Suckers averaged 9.2 inches in total length (4.3 to 19.5 inches).

Fish concentrated wherever cover furnished concealment much the same as in the canals which had an abrupt decrease in flow before headgate closure. Only 12.8 per cent of the total trout and whitefish poundage taken in the Spain-Ferris Canal was found in Section 1 behind the headgate (Fig. 3), which is considerably less than 28.5 per cent found in Section 1 of the Middle Creek Supply Canal or the 65.2 per cent for the same section of the Kleinschmidt Canal. Practically all of the poundage taken in this first section of the Spain-Ferris Canal was located in a 40-foot pool (maximum depth 30 inches) about 260 feet downstream from the headgate. A 75-foot pool (maximum depth 14 inches) held all of the fish taken from Section 2. Three-fourths of the fish in Section 3 were found in a 25-foot pool (maximum depth 30 inches), and the remaining 1/4 were taken from two adjacent and shallower pools. These first 900 feet of the canal more closely resemble a natural stream than a diversion ditch. Pools are separated by riffles, bottom materials are predominantly rubble and gravel, and channel banks are well covered by willows and smaller shrubs.

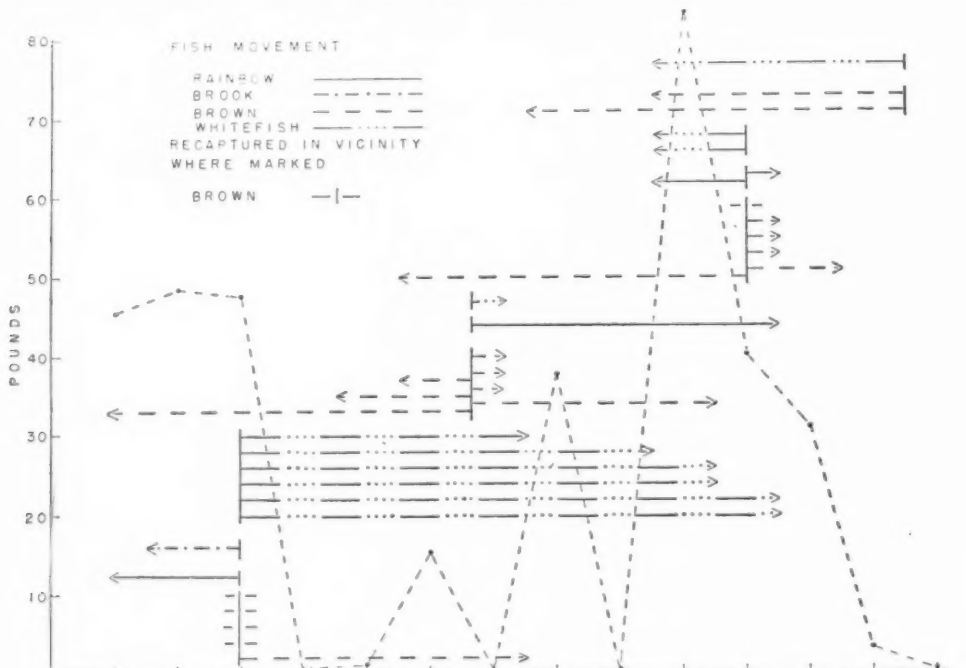

FIG. 3. Pounds of trout and whitefish taken in each 300-foot section of Spain-Ferris Canal (superimposed broken line), and direction and distance marked recoveries traveled from point of release (vertical bars). Zero feet at the headgate. Each symbol signifies an individual fish.

Less than one per cent of the total game fish poundage was taken from Sections 4 and 5, each of which contained two to eight inches of water. Trout and whitefish taken from Sections 6 through 12 (2100 feet) represented 58.7 per cent of the total game fish poundage captured (Fig. 3). Standing water depths increased gradually from 12 inches in Section 6 to 24 inches in Section 9, and remained deep through Section 12. Cottonwood trees and willows shaded Sections 6 through 8, and continuous islands of *Ranunculus aquatilis* gave cover in Sections 9 through 12. The remaining sections in the study area (13 and 14) were shallow because of an increased gradient. Only a few fish were taken in this 600-foot section of ditch and most of these were found under a bridge in Section 13.

Four 500-foot sections were shocked during the marking period, and 85 fish were fin-clipped (Table 8). Subsequent recoveries included 49.0 per cent of the trout, 47.6 per cent of the whitefish and none of the suckers. Only one fish (a trout) less than seven inches in length was retaken.

Most of the recoveries (51.4 per cent of total) were recaptured as far as 2550 feet downstream from the point of release (Fig. 3). Recoveries which moved upstream (34.3 per cent of total) had traveled from 350 to 1800 feet. No movement was shown by 14.3 per cent of recoveries. This down-canal trend is opposite to the trend of movement found in canals where distinct water reductions were made before headgate closure.

SUMMARY

1. Four canals from the West Gallatin River, Montana, were selected for a study of trout, whitefish, and sucker movement following abrupt water reductions.

2. Fish taken from each canal during the regular irrigation season were marked and returned to the water within the section where caught.

3. The entire distance from the headgate to the last section in which fish were marked (4200 to 7500 feet) was censused in each canal after the water was turned off. Elapsed time between dates of marking and dates of headgate closure ranged from 51 to 74 days.

4. Water in three canals was decreased three days prior to headgate closure. One of these ditches had a period of reduced flow coincidental with the natural lowering of river level. The fourth canal served as a control, and it was turned off with-

TABLE 8.—FISH MARKED AND RELEASED IN THE SPAIN-FERRIS CANAL, SEPTEMBER 12

Species	Number	Weight (pounds)	Length in inches	
			Average	Range
Rainbow	10	3.13	8.4	6.4 - 12.7
Brook	3	0.52	7.9	7.2 - 8.4
Brown	37	15.11	9.6	6.9 - 21.4
Cutthroat	1	0.12	7.6	... - ....
Whitefish	21	3.78	7.0	3.6 - 12.6
Suckers	13	5.86	9.0	4.7 - 17.8
Total	85	28.52		

out a preliminary reduction period.

5. Fish concentrations were found wherever brush, undercut banks, and pools furnished concealment. These areas of concentration were often small and widely separated, suggesting that reduced flow effected a redistribution of the fish population.

6. Game fish concentrations were found immediately behind the headgate in the two canals having one period of decreased flow before headgate closure. Of the marked recoveries, 73 per cent in one canal and 100 per cent in the other were recaptured upstream from point of release for distances varying from 150 to 7500 feet.

7. The smallest marked fish (a 4.3-inch eastern brook trout) which moved upstream traveled 1750 feet. A 12.9-inch rainbow trout traveled a maximum distance of 7500 feet.

8. Only 12.1 per cent of the game fish poundage in the control canal was found in the section immediately behind the headgate, and 51.4 per cent of the marked recoveries were recaptured as far as 2550 feet downstream from the point of release.

LITERATURE CITED

CLOTHIER, W. D. 1953. Fish loss and movement in irrigation diversions from the West Gallatin River, Montana. Jour. Wildl. Mgt., **17**: 144–158.

Accepted for publication February 28, 1953.

THE VALUE OF WATERFOWL REFUGES IN ILLINOIS

Frank C. Bellrose

Illinois Natural History Survey, Urbana, Illinois

In recent years the value of waterfowl refuges has been questioned by hunters, game biologists, and conservation administrators. Hunters, who have seen large numbers of waterfowl within refuge areas during hunting seasons, have complained that refuges give ducks too much protection. Biologists, who have witnessed large kills of waterfowl adjacent to refuge borders, have expressed concern that refuges were greater death traps than sanctuaries. Cost-conscious conservation administrators have questioned the value of refuges on the grounds that hunting regulations alone could adequately regulate the kill.

The value of a refuge to waterfowl is determined by whether it is within the breeding, migration, or wintering grounds of the birds under consideration. Refuges for ducks in Illinois are most appropriately classed as migration areas, and consequently, information presented in this paper applies to this type of refuge.

Waterfowl refuges in Illinois may be classified as natural, private, or public. Natural refuges occur where lakes embrace such extensive areas of open water as to provide waterfowl with resting grounds which are relatively undisturbed by hunters. There are two notable areas of this type: Upper Peoria Lake of about

9,000 acres in the Illinois River Valley above Peoria, and Cooper Lake, an impounded reach of the Mississippi River between Keokuk and Ft. Madison, Iowa. However, their physical nature is such that these lakes are primarily suited for diving ducks, and only secondarily for dabbling ducks.

Private refuges are extensive only in the Illinois River Valley where there are approximately 400 duck clubs. Thirty of these clubs control 1,000 or more acres, and about 20 of them maintain refuges, each one of which covers a minimum of several hundred acres; three clubs possess refuge areas of 1,000 or more acres.

There are 13 public waterfowl refuges in Illinois (Fig. 1), 6 of which are administered by the Illinois Department of Conservation, 6 by the United States Fish and Wildlife Service, and one by the Forest Preserve District of Cook County. Of the 57,350 acres (Table 1) in the refuge areas, about 5,000 are open to hunting. In addition there are other public areas designated primarily as shooting grounds.

The first public waterfowl refuge in Illinois was established in 1927 at Horseshoe Lake, Alexander County, by the Department of Conservation. It was not until 1943 that the next refuge area, Rice Lake, was acquired. Since then the Anderson Lake, Union County, Sanganois, and Mermet refuges have been obtained and additional acreage added to the Horseshoe Lake area. The Horseshoe Lake and Union County refuges are of greatest value for Canada geese and of lesser value for ducks.

The United States Fish and Wildlife Service commenced acquisition of the Lake Chautauqua Levee and Drainage

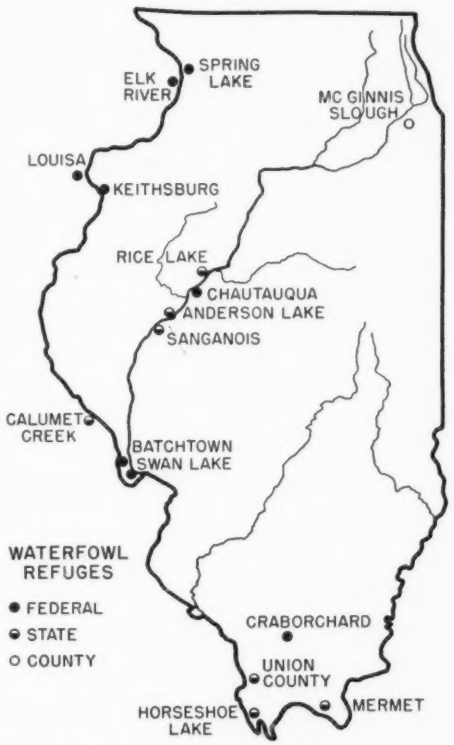

FIG. 1. Location of public waterfowl refuges in Illinois and bordering the Mississippi River in Missouri and Iowa, 1952.

District for a waterfowl refuge in 1936, and it was completed in 1940. Subsequently, Spring Lake, Keithsburg-Louisa, Batchtown and Swan Lake were established as federal refuges on War Department lands along the Mississippi River. Swan Lake was closed to hunting in 1943, and the other areas in 1946. The Crab Orchard National Wildlife Refuge was established in 1947, primarily for Canada geese and secondarily for ducks.

VALUE FOR WATERFOWL

In the early 1900's the more observant owners of duck lands in the Illinois River Valley found that a refuge, or a

TABLE 1.—WATERFOWL REFUGES IN ILLINOIS, EXCLUSIVE OF PRIVATE CLUB REFUGES IN 1952

Name of Area	Location by County	Managed by	Number of Acres
Horseshoe Lake	Alexander	Dept. of Cons.	5,320
Union County	Union	" " "	5,811
Meremet	Massac	" " "	1,900
Rice Lake	Fulton	" " "	2,370*
Anderson Lake	Fulton	" " "	1,862*
Sanganois	Cass	" " "	3,160*
Lake Chautauqua	Mason	U.S.F. & W. Serv.	4,470††
Crab Orchard	Williamson	" " " " " "	22,000
Swan Lake	Calhoun	" " " " " "	4,327
Batchtown	Calhoun	" " " " " "	1,504
Keithsburg	Mercer	" " " " " "	1,405
Spring Lake	Carroll	" " " " " "	2,907†††
McGinnis Slough	Cook	County Forest Preserve	314
Total			57,350

* About half of this acreage in public shooting ground.

†† Liverpool Lake portion open to public hunting.

††† North end open to public hunting.

"rest ground" as they were more commonly called, was of value in building up and holding concentrations of waterfowl on their properties. It was evident that club holdings without a refuge attracted comparatively few ducks except for short periods during major flights. Numbers of ducks using the property and length of time they remained increased when a refuge was included in the club management plan.

Effect of shooting and other hunter disturbance on duck populations is shown (Table 2) by numbers of ducks per acre on three areas which afforded varying degrees of security.

Lake Chautauqua, a national wildlife refuge, provided complete protection to ducks on 3,562 acres; Clear Lake was both a club refuge and shooting ground with about half of its 1,716-acre basin unshot; Muscooten Bay was owned by many small clubs, and consequently there was no large unshot or undisturbed area among its 2,240 acres of water.

In most years it was not apparent that food resources or other environmental conditions made one area markedly more attractive than another. However, in 1940, 1945, and 1946, native duck food resources in Clear Lake were

TABLE 2.—AVERAGE NUMBERS OF DUCK DAYS PER ACRE DURING A 50-DAY PERIOD, OCTOBER 18—DECEMBER 6, 1940–1951, ON CHAUTAUQUA NATIONAL WILDLIFE REFUGE, CLEAR LAKE—A CLUB REFUGE AND SHOOTING AREA, AND MUSCOOTEN BAY—AN AREA WITH NO REFUGE

Year	Lake Chautauqua	Clear Lake	Muscooten Bay
1940.....	4,016	2,329	..
1941.....	6,564	786	47
1942.....	6,946	885	51
1943.....	6,973	322	..
1944.....	8,203	2,674	2
1945.....	2,397	1,329	7
1946.....	1,082	918	..
1947.....	1,935	672	5
1948.....	3,045	506	11
1949.....	2,206	317	126
1950.....	3,537	130	44
1951.....	1,214	70	215
Average....	4,010	911	56

much greater than in Lake Chautauqua or Muscooten Bay; in the other years, there was a paucity of duck foods in all three lakes. It was evident that security constituted the principal factor governing the relative degree of use made of these areas by waterfowl. Waterfowl averaged over 16 times as abundant per acre on Clear Lake as on Muscooten Bay, and over 4 times as numerous per acre on Lake Chautauqua as on Clear Lake.

Another opportunity for evaluating the importance of refuges in building up concentrations of waterfowl was afforded when several areas along the Mississippi River were closed to hunting during the 1940's. Weekly or bi-weekly waterfowl censuses were taken before the refuges were established as well as in subsequent years. Data from the censuses (Table 3) reveal the extent to which these refuges were instrumental in increasing local populations of waterfowl. Within a few years after establishment, and with no improvement in habitat conditions, there were large increases in the average daily number of ducks utilizing the refuges.

Although no waterfowl census of Swan Lake Refuge was taken by Natural History Survey personnel during the initial three years of its establishment, records of Mr. Edward Davis, refuge manager, reveal that in the first year, 1943, there were no more than 20,000 ducks at any time, or about the same number as in 1941 (Table 3). By 1945, the third year of its establishment, there were 500,000 mallards and pintails at the peak of migration. Although the number of ducks frequenting this refuge declined after 1946, there were from two to five times as many ducks during the 1947–1951 period as there were prior to its closure to hunting.

Despite a natural refuge formed by impounded water of the Mississippi River above the dam at Clarksville, Missouri, closure of an adjacent 500-acre shoal-water area by the Missouri Conservation Commission in 1949 brought about a sizeable increase in waterfowl populations (Table 3). Prior to the establishment of the refuge, pintails were rarely observed, but, subsequently, thousands of pintails stopped; they formed

TABLE 3.—THE AVERAGE DAILY POPULATION OF DUCKS BASED ON WEEKLY OR BI-WEEKLY CENSUSES BETWEEN OCTOBER 18—DECEMBER 6, 1941, 1946–1951, ON FOUR AREAS IN OR NEAR THE MISSISSIPPI RIVER. SWAN AND GILBERT LAKE WERE CLOSED TO HUNTING IN 1943, BATCHTOWN AND KEITHSBURG-LOUISA IN 1946, AND CLARKSVILLE IN 1949

Year	Swan and Gilbert Lake (Pool #26)	Batchtown (Pool #25)	Clarksville (Pool #24)	Keithsburg-Louisa (Pool #17)
1941	18,100	1,800	5,400	....
1946	439,700	80	5,400	6,200
1947	70,600	8,200	700	6,100
1948	54,200	44,700	2,400	30,100
1949	94,200	14,800	7,000	24,600
1950	38,100	15,000	13,200	16,100
1951	89,500	14,000	18,200	58,100
Average for years of refuge	131,050	16,130	12,800	23,533

about 40 per cent of the duck population in the area, 1949–1951.

In 1941, open water above the Batchtown Dam on the Mississippi River provided partial protection for waterfowl, but there was some disturbance from boats and hunting. However, with the closure of an adjacent 1,500-acre shoalwater area, the number of waterfowl increased from two to eight times.

No censuses were made of the Keithsburg, Illinois area or the Louisa area, near Wapello, Iowa, before they were closed to hunting in 1946. There were no natural refuges in the vicinity, however, and it seemed reasonable to assume that few ducks utilized these areas before they were closed to hunting. Small numbers of ducks stopped in 1946 and 1947, the first two years the areas were closed to hunting but, subsequently, much larger numbers of waterfowl utilized these areas (Table 3).

The value of a flyway refuge to waterfowl is two-fold: It enables migrating birds to replenish depleted energy reserves and adds to the available duck food resources of the entire flyway.

Weights of mallards shot in the Illinois River Valley and in the Mississippi River Valley near Burlington, Iowa, (Bellrose and Hawkins, 1947) may reflect the importance of refuge areas to the physical condition of these birds. The mallards weighed in the Illinois Valley were about 0.1 pound heavier than the others. Those taken in the Illinois Valley were from areas adjacent to private or federal refuges whereas most of those shot near Burlington, Iowa, were transient mallards. Although the food resource in waste corn was as abundant in the mechanically picked fields about Burlington, Iowa, as in the Illinois River Valley, little was available to ducks because of lack of a suitable rest area within their daily cruising range.

Some indication of the number of duck days provided by Illinois waterfowl refuges during the fall is given in Tables 2 and 4. Because they are capable of searching out from a refuge for food over an area circumscribed by a radius 25–30 miles in length, ducks can concentrate in very large numbers on areas used for resting and desultory feeding. Thus, a small flyway refuge can be more valuable per unit of area than a large wintering ground refuge because of the ability of ducks to feed over a much greater area than that covered by the refuge itself. The habit of mallards to feed at distances up to 25–30 miles from a refuge is supported not only by direct observation, but also by the large proportion of banded birds taken within this distance (Table 5).

Tremendous amounts of duck food are unavailable to waterfowl each year in Illinois because in many sections of the state rest areas are not in juxta-

TABLE 4.—THE NUMBER OF DUCK DAYS OF USE PER ACRE ON THREE NATIONAL WILDLIFE REFUGES ALONG OR NEAR THE MISSISSIPPI RIVER DURING A 50-DAY PERIOD FROM OCTOBER 18—DECEMBER 6, 1946–1951

Year	Swan Lake	Batchtown	Keithsburg-Louisa Districts
1946.....	3,950	3*	83
1947.....	816	272	82
1948.....	625	1,478	405
1949.....	1,088	496	332
1950.....	440	499	217
1951.....	1,034	465*	78
Average..	1,325	536	199

* Largely drained by reduced river level.

TABLE 5.—THE PROPORTION OF CURRENT-YEAR BAND RETURNS BY MILEAGE ZONES FOR MALLARDS BANDED AT SPRING LAKE, CARROLL COUNTY; MCGINNIS SLOUGH, COOK COUNTY; AND LAKE CHAUTAUQUA, MASON COUNTY

Distance in Miles	Spring Lake 1946–1948		McGinnis Slough 1942–1947		Lake Chautauqua 1947, 1949–1951	
	No.	Per cent	No.	Per cent	No.	Per cent
0–25	151	46.8	213	26.7	167	52.0
25–50	8	2.5	68	8.6	17	5.3
50–75	13	4.0	51	6.4	16	5.0
75–100	16	5.0	99	12.4	7	2.2
100–200	27	8.4	114	14.4	14	4.3
200–300	16	5.0	80	10.0	40	12.5
300–400	15	4.7	45	5.7	23	7.2
400–500	31	9.6	42	5.3	24	7.5
500–600	18	5.6	39	4.9	4	1.2
600–700	11	3.4	18	2.3	2	0.6
700–800	6	1.9	15	1.9	7	2.2
800– +	10	3.1	11	1.4	..	...
Total	322	100.0	795	100.0	321	100.0

position with food supplies. In recent years mechanical pickers have left about 10 per cent of the corn crop in the fields (Bateman, Pickard and Bowers, 1952) and at least one-fourth of this amount forms a potential source of food for waterfowl.

Flyway refuges, in making more food available, keep waterfowl on flyway areas for a longer period of time, thereby relieving their demands for food on wintering grounds. At present it is not known whether wintering grounds of the Mississippi Flyway provide sufficient quantity and quality of food to keep waterfowl in good condition until spring migration, but if a shortage of quality food exists on wintering areas, then it would be most important to retain waterfowl on flyway areas as long as possible.

VALUE FOR HUNTERS

As previously pointed out, duck club personnel have realized the value of refuge areas to hunting for many years. Heilner (1943) shot at many duck clubs across the nation and observed the effect of rest days and rest areas on shooting. He stated (p. 492): "I cannot repeat too often, as I have done elsewhere in this book, that where fowl are heavily shot at, they will not remain."

Most flyway refuges are too small to provide food for the hordes of waterfowl that concentrate on them. Consequently, as shown by the large proportion of band returns taken by hunters within a 25-mile radius of refuge areas (Table 5) mallards and other ducks fan out from refuges to feed, thereby giving hunters an opportunity to harvest large numbers. It is evident from the proportion of band returns from various mileage zones radiating out from refuge areas that mallards spend considerable time in a flyway refuge area before migrating elsewhere.

Adequate kill records from refuge areas are lacking prior to their establish-

ment, thus, "before and after" comparisons cannot be made. It is readily evident, however, that duck kills are high on lands adjacent to major waterfowl refuges in Illinois. Tables 6 and 7 show the kill of ducks, as determined by Edward Davis, for public shooting grounds adjacent to the Batchtown and Swan Lake National Wildlife Refuges. Additional ducks were bagged on other areas within a 25-mile radius of these refuges, which would add materially to the total kill given in the tables.

In comparison with the average number of ducks found using the refuges during open season, the duck kill appeared to be moderate at Swan Lake Refuge, and very high at Batchtown Refuge. Daily rate of mallard kill has been found to be approximately the same during the hunting season in the Mississippi Flyway (Bellrose and Chase, 1950). Therefore, with the open season in Illinois one-third or less of the total open season within the United States portion of the Mississippi Flyway, and with a flyway shooting loss of about 32 per cent (Bellrose and Chase, 1950), the kill in the vicinity of Swan Lake Refuge was considered ample but not excessive. Duck kill was considered excessive in the vicinity of Batchtown Refuge.

TABLE 6.—THE NUMBER OF DUCK HUNTERS CHECKED, THEIR KILL, AND THE ESTIMATED NUMBER OF HUNTERS AND TOTAL DUCK KILL, ON THE PUBLIC SHOOTING GROUNDS ADJACENT TO THE SWAN LAKE NATIONAL WILDLIFE REFUGE, 1947–1951

Year	Hunters Checked	Hunters Estimated*	No. Ducks Killed Checked	No. Ducks Killed Estimated**	Mean duck population during season	Proportion killed
1947.....	545	3,057	680	3,814**	71,074	5.36
1948.....	505	5,090	577	5,818	64,305	9.05
1949.....	1,517	6,433	2,157	9,148	113,841	8.04
1950.....	1,419	5,992	1,409	5,949	45,747	13.00
1951.....	1,987	.....	2,356	.....	.....	.....
Total & Average				24,729	294,967	8.39

TABLE 7.—THE NUMBER OF DUCK HUNTERS CHECKED, THEIR KILL, AND THE ESTIMATED NUMBER OF HUNTERS AND TOTAL DUCK KILL ON THE PUBLIC SHOOTING GROUNDS ADJACENT TO THE BATCHTOWN NATIONAL WILDLIFE REFUGE, 1948–1951

Year	Hunters Checked	Hunters Estimated*	No. Ducks Killed Checked	No. Ducks Killed Estimated**	Mean duck population during season	Proportion killed
1948.....	806	3,025	1,960	7,357	50,351	14.61
1949.....	1,029	2,027	1,498	2,951	16,587	17.79
1950.....	1,512	1,512	2,189	2,189	15,017	14.58
1951.....	437	.....	920	.....	.....	.....
Total & Average				12,497	81,955	15.24

* On the basis of car counts.

** On the basis of average tallied bag times estimated number of hunters.

EFFECT OF REFUGE SIZE

Size of a refuge proved important in determining the relative number of ducks that used it as well as the degree of protection it afforded them. This was apparent in a comparison of numbers of ducks per acre at Swan Lake Refuge and Batchtown Refuge (Table 4). The refuges are located only about 12 airline miles apart. Food resources at the Batchtown area have been greatly superior to those at Swan Lake, yet in most years there have been more ducks per acre on the 4,327-acre Swan Lake area than on the 1,504-acre Batchtown area. At the start of the 1940 season, there were about 70,000 ducks on Batchtown Refuge. After two days of intensive gun fire from two sides of the closed area, about 60,000 mallards and pintails departed, and thereafter, the refuge contained no more than 10,000 ducks. There was no noticeable exodus from other refuges at the time of the loss at Batchtown, indicating that the heavy "cannonading" of the first two days was responsible.

Another example is found in the comparative number of ducks frequenting Lake Chautauqua Refuge and adjacent Clear Lake (Table 2). As mentioned earlier, about half of the 1,716 acres in Clear Lake were hunted, whereas none of the 3,562 acres of water in Lake Chautauqua were hunted. The effect of a smaller refuge area can be seen in that over four times as many ducks per acre were found on Lake Chautauqua than on Clear Lake (Table 4).

A small body of water can be an important waterfowl refuge as attested by the numbers frequenting McGinnis Slough. Although waterfowl census records are available for only one year, 1947, they show that there was an average of 526 duck days per acre from October 18 through November. McGinnis Slough contains only about 314 acres of water surface, but surrounding uplands are closed to hunting thereby giving the water area adequate protection from disturbance.

All the refuge areas discussed appear to provide a balanced relationship between population and kill with the exception of Batchtown Refuge. Here the kill seems too high for the number of duck days provided. High kill is believed to occur largely because of extensive shooting grounds flanking two sides of the closed area with no natural conformation marking the boundary of the refuge. Where trees, banks, levees, or some easily defined landmark forms a refuge boundary, most mallards and pintails—the two major species at Batchtown—have been remarkably adept at adjusting their habits in relation to the shooting zones.

The most advantageous size of a flyway refuge depends on amount of open water and degree of disturbance on surrounding lands. A small body of water, such as McGinnis Slough, can be an effective refuge with adequate protection on border lands. Similarly, Keithsburg and Louisa Refuges consist of small bodies of water surrounded by land on which trespass is prohibited, thereby inducing an appreciable number of ducks to congregate on the small water areas (Table 3). Calumet Creek Refuge, managed by the Missouri Conservation Commission at Clarksville, Missouri, is only about 500 acres in size, yet waterfowl find it an excellent resting ground because it is bounded by a highway and railroad on one side, and by the river channel on the other. Hunters,

therefore, are barred by landscape features from shooting too near the closed area.

Where marsh vegetation, woods, or land break up the conformation of open water, disturbance caused by shooting and boating is lessened. On lakes used for both shooting and resting areas, those water areas with a paucity of islands, points or marsh would require the largest refuge areas. Observations in Illinois indicate that to be most effective, refuges on such lakes should contain at least 1,000 acres. Where adjacent lands are not hunted or where sloughs, marsh or wooded ponds, bays or inlets occur, satisfactory refuges can be much smaller. Protected ponds as small as 30 acres have attracted and held several thousand mallards.

DISTANCE APART

Ideally, waterfowl refuges on migration routes should be about 50 miles apart where waterfowl habitat is continuous and fall food generally available as it is along the Illinois River, and along the Mississippi River between Lake Pepin, Minnesota, and Alton, Illinois. Mallards range out about 25 miles from rest lakes searching for food, showing as much inclination to move north as south (Fig. 2). Therefore, by establishing refuges 50 miles apart on continuous waters, such as a river or a chain of lakes, mallards, and probably many other species would be able to utilize intervening waters for feeding. Hunters would be aided because the entire area would be within daily flight range of feeding waterfowl.

Mallards on McGinnis Slough exhibited a tendency to "spill out" of the small area to the nearby Illinois River Valley. On leaving McGinnis Slough they were especially prone to fly only from 75 to 100 miles. In migrating from Spring Lake Refuge, mallards were likely to visit the Illinois Valley, 75 to 200 miles distant, or move 400 to 500 miles to their Arkansas wintering grounds. Mallards banded at Chautauqua—once having left the refuge area—moved from 200 to 500 miles before alighting in large numbers.

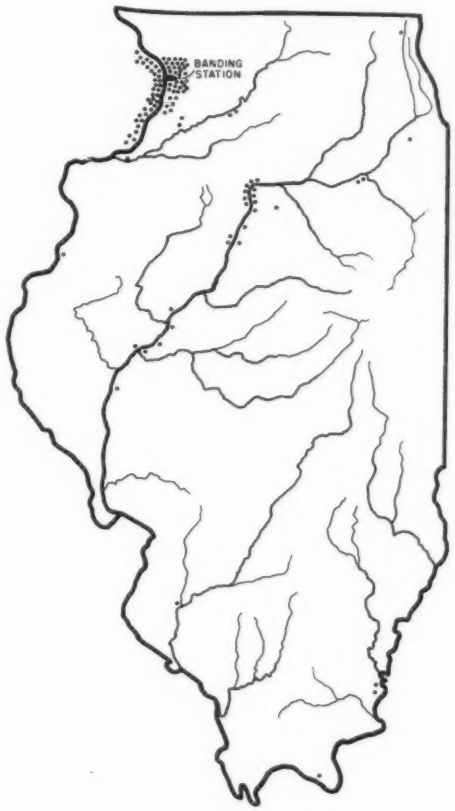

FIG. 2. Band returns in and adjacent to Illinois, 1946, from mallards banded that year at Spring Lake National Wildlife Refuge, Savanna, Illinois.

The varying distances that mallards flew south in migrating from Illinois

refuges was, at least partially, dependent upon availability of suitable habitat. However, although suitable habitat was available immediately south of Spring Lake, most mallards, upon leaving there, preferred to fly to their principal wintering grounds.

Where waterfowl habitat is widely separated, as in the Great Plains, it would appear desirable to have waterfowl refuges between a minimum of 200 and a maximum of 500 miles apart.

CONCLUSIONS

Flyway refuges in Illinois are important both to waterfowl and to hunters. Without suitable places to stop for resting and feeding during the hunting season, migrating waterfowl, particularly mallards and pintails, would move on to wintering grounds. Refuges make more ducks available to hunters on migration routes by building up local concentrations from which mallards and some other species fan out to feed over a radius of about 25 miles. Band returns and kill data demonstrate that ample numbers of ducks are killed in the vicinity of flyway refuges in Illinois. In the area of one refuge, Batchtown, the kill of ducks is probably excessive.

Flyway refuges put more food within reach of waterfowl by enabling them to feed in mechanically picked cornfields and in hunted lakes and marshes within daily cruising range of refuge areas. Without a place to rest undisturbed, waterfowl are likely to make use of such areas only for a few days during migration. By using more of the food resources of the flyway, ducks become less dependent upon the food resources of the wintering grounds, which may or may not be adequate.

The most desirable size for refuges along migration routes of waterfowl is dependent upon many factors: shape of the body of water, whether or not shooting is conducted on part of the area, degree of protection on surrounding lands, and distance from other refuges. Where shooting on adjacent lands is a potentiality, if not an actuality, refuges for migrating ducks should probably include at least 1,000 acres.

Where waterfowl habitat is continuous, refuges ideally should be about 50 miles apart. This is based on the principle that ducks fan out over a radius of about 25 miles to feed.

LITERATURE CITED

BATEMAN, H. P., G. E. PICKARD, and W. BOWERS. 1952. Corn picker operation to save corn and hands. Univ. of Ill. College of Agri. Circ. 697, 11 pp.

BELLROSE, F. C. and A. S. HAWKINS. 1947. Duck weights in Illinois. Auk, **64**: 422–430.

——— and E. B. CHASE. 1950. Population losses in the mallard, black duck and blue-winged teal. Ill. Nat. Hist. Survey Biol. Notes 22, 27 pp.

HEILNER, V. C. 1943. A book on duck shooting. Alfred A. Knopf, New York, 540 pp.

Accepted for publication March 21, 1953.

PLANNING WILDLIFE EXPERIMENTS INVOLVING PERCENTAGES [1]

David E. Davis and Calvin Zippin

The wildlife manager is frequently faced with the task of planning a program to discover if there exists a difference between two groups of animals as to relative frequency of some characteristic, relative frequency being expressed as a percentage. His planning will be greatly assisted if he can estimate approximately how many specimens need to be examined so that a given observed difference in percentage will be established as statistically significant.

For example, one may wish to compare the percentage of released game-farm pheasants having some infection with the percentage of infected pheasants in natural populations in an area. To make the comparison, a number of game-farm birds (which had been marked when released) would be collected and examined. Similarly, a number of wild birds would be examined. Previous information suggested a greater susceptibility of game-farm birds to the infection than wild birds. The problem is to know how many birds are needed in each group to establish, as significantly greater than zero, an observed difference of a particular magnitude. With proper caution, the charts presented in this paper can be used to determine about how many specimens are needed in problems where two observed percentages are to be compared.

In order to use the charts one must be able to estimate the approximate percentages which might be observed. For example, suppose that one wishes to study the age distribution of elk in different areas. Suppose, further, that from some preliminary observations or perhaps from published data one has reason to expect that variations from area to area are such that about 20 per cent of the elk will be yearlings in one area and about 10 per cent in another area.

With these guesses one can proceed immediately to use Figure 1 for finding the number of elk that must be observed. The method is as follows:

1. Find the vertical line whose value is that of the smaller of the two percentages being compared (here, 10 per cent).
2. Follow this vertical line up until it crosses the curved line corresponding to the other percentage (here, 20 per cent).
3. From this point of intersection read horizontally to determine the value of the horizontal line on which the intersection occurs. This value will be the number required in each group (here, about 100), if we wish to establish the 10 per cent difference, (20–10), as statistically significant.

A few words concerning the derivation of Figure 1 may help. The basic formula for the figure is an expression for the ratio of the difference between two percentages to the standard deviation of the difference (Hill, 1950: 111;

[1] Contribution from the Division of Vertebrate Ecology and the Department of Biostatistics of the Johns Hopkins School of Hygiene and Public Health.

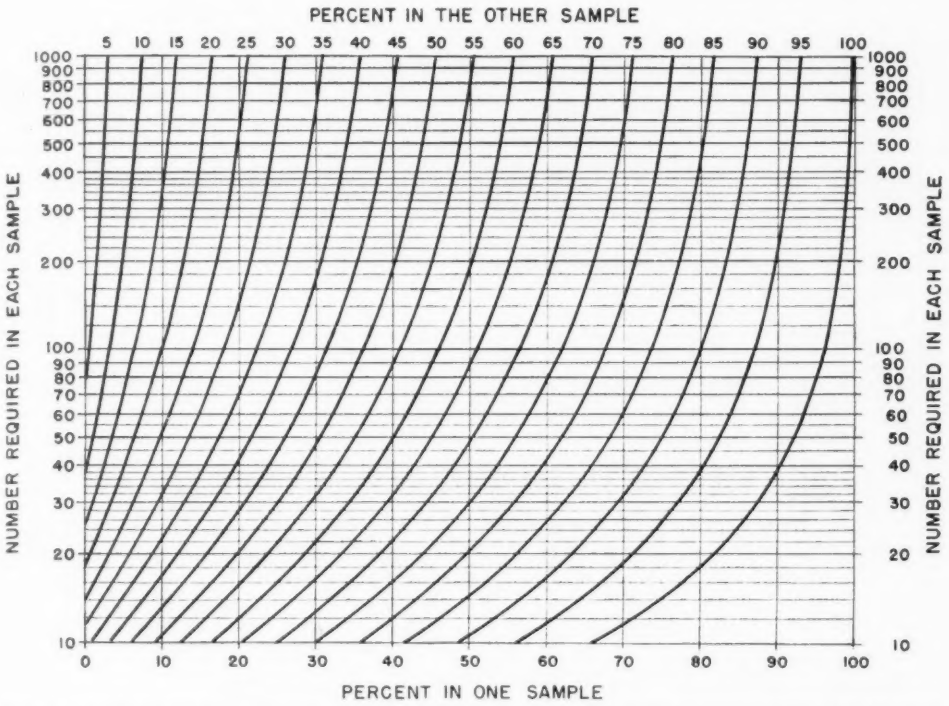

FIG. 1. Chart for estimating number of animals required in each sample for statistical significance, between percentages. Probability of Type I error = .05. Probability of Type II error = .50.

Pearl, 1940: 329). This ratio may be written as

$$(1) \qquad R = \frac{p_1 - p_2}{\sqrt{\frac{pq}{n_1} + \frac{pq}{n_2}}}$$

or, when $n_1 = n_2 = n$,

$$(2) \qquad R = \frac{p_1 - p_2}{\sqrt{\frac{2pq}{n}}}$$

solving this equation (2) for n,

$$(3) \qquad n = \frac{2R^2pq}{(p_1 - p_2)^2}$$

This last equation was used to plot the curved lines. In the equation (3)

n = the number required in each sample.

p_1 = the expected percentage in one sample which shows the characteristic under study.

p_2 = the percentage expected to be observed in the other sample.

R = a numerical value whose size is determined by an arbitrarily selected level of significance. As will be explained below, R = 2 in the calculations on which Figure 1 is based.

p = the percentage in both groups (or samples) combined. Here, since the number in each group is assumed to be the same,

$$p = \frac{p_1 + p_2}{2}$$

$$q = 100 - p$$

To go back to the pheasant example the letters would mean:

n = the number of game-farm birds collected and also the number of wild birds collected.

p_1 = the expected percentage of infection of game-farm birds.

p_2 = the expected infection of wild birds.

$p = \frac{p_1 + p_2}{2}$ = the expected infection from both groups in percent of all birds examined.

The vertical scale on the figure was made logarithmic merely because this would space the lines more conveniently than would an arithmetic scale.

The reason for using $R = 2$ may be briefly explained as follows. With limitations which will be mentioned later, a difference in percentages, $p_1 - p_2$, is judged as to its statistical significance according to the value of the ratio R. The larger the ratio, the greater is the statistical significance of the difference, i.e., the less likely it is that the observed difference could be due to chance. When the ratio equals 2, one can make the statement that if there is in reality no difference in percentages between the two groups, one would expect to see a difference as great as or greater than that observed only about 5 percent of the time in repeated pairs of samples of size n_1 and n_2. Thus, only five times in a hundred would one incorrectly claim, on the basis of sample results, a significant difference between the two groups when none really exists. This kind of error (claiming a difference when none exists) is called a Type I error in statistical terminology. It is the probability of committing a Type I error which is commonly referred to in stating the results of tests of significance. If $R = 2$, the probability of a Type I error equals .05. This significance level has become the conventional one for most experimental work and is the level chosen for use in this paper.

In the case of the pheasant example, the use of $R = 2$ means that, collecting the number of birds indicated by the chart for the predicted percentage difference, only 5 times in a hundred, in samples of this size, would a difference as large as the expected difference be observed if there really is no difference in the infection of game-farm birds and wild birds.

The selection of a larger value of R would increase the confidence with which one would ascribe statistical significance to a given difference, but it would also require that a larger number of specimens be examined. In some instances when the consequence of committing a Type I error (i.e., concluding that the groups are different when they are not) is not serious, it may be satisfactory to let R be some value less than 2. For example, R would be set at 1.44 if one desired that the probability should be .15 of stating that a difference exists when actually there is no difference between the two groups from which the samples are drawn. A chart similar to the one presented could be prepared giving the sample sizes required when working at the 15 percent confidence level instead of the 5 percent level. These sample sizes would be less than the corresponding ones found on Figure 1. Thus, as is logically to be expected, increased insurance against error necessitates increased expenditure of effort and

conversely, decreased security reduces the amount of work required.

Tabled values of R and of the corresponding significance levels may be found in most elementary statistical texts (Pearl, 1040: 480), and such tables may be consulted when, after the data have been gathered, the statistical significance of an observed difference is to be judged.

Size of samples necessary to consider an observed difference of a certain size to be significant has been determined. It must now be considered how often a difference of this size in repeated samples will be observed when the percentage having the attribute in the first population is P_1, and in the second population is P_2. In the following discussion capital letters (P) refer to true percentages, whereas small letters (p) refer to the percentage in a sample. If $P_1 = P_2 = P$, then about half the time repeated samples from Populations 1 and 2 will give observed p's less than P and half will be greater than P. If each sample from Population 1 is paired with a corresponding sample from Population 2 and the differences between the observed p's in each pair listed, it would be found that the differences $p_1 - p_2$, center about zero difference with approximately half greater than zero and half less than zero.

Similarly, if P_1 does not equal P_2 the repeated samples from Population 1 will have values of p_1 centering about P_1 with about half above and half below; observed p's from Population 2 will center about P_2 with about half above and below. Differences between paired samples will also distribute themselves about $P_1 - P_2$ with about half the differences on either side.

Thus, only half the time will repeated sampling differences equal or exceed the true difference $P_1 - P_2$. This chance sampling variation could be verified by drawing successive handsful of marbles from bags containing P_1 and P_2 red marbles and observing the percentage of red marbles in each handful. (The marbles from each handful must be returned to the bag and the bag shaken between drawings.)

Let the elk population again be considered and assume that 20 per cent are yearlings in one area and 10 per cent in another. From the above discussion it should be evident that if repeated samples were drawn in the first area and paired with corresponding samples drawn in the second area, and the differences between the proportion of yearlings in each pair tabulated, it would be seen that approximately half the differences would be less than the population difference of 10 per cent (20 per cent − 10 per cent) and about half would be greater. The average of the observed differences would be close to the population difference of 10 per cent, but this expected value will be equalled or exceeded only half the time in repeated samples.

Figure 1 tells how many observations are required so that an observed difference will be statistically significant. If, in the conception of the experiment, the worker believes the population proportions to be specified values and, therefore, the difference between them to be of a certain magnitude, he should, in the light of the previous discussion, be aware that his sampling differences will equal or exceed the true difference only half the time. Therefore, if he has been correct with respect to the values of P_1 and P_2, 50 percent of his sample differences

will be less than $P_1 - P_2$, (the expected difference); if he has used the number of animals given in Figure 1, he will not be able to claim significance for this portion of his results. Thus, half of the time, on the basis of sample differences, the error will be made of not claiming a population difference when, in fact, it does exist. This failure to recognize a true difference is called a Type II error and Figure 1 is constructed so that the probability of committing a Type II error is 50 percent.

In the comparison of the percentage of the elk population that is yearlings, assume that the difference between the two areas really is 10 percent (i.e., 20 percent − 10 percent). In any particular sample one might get 16 per cent for the first area and 11 per cent for the second area. In this case, it would be stated that no difference has been shown to exist even though a difference does exist. This is a Type II error. In contrast, one might get 22 per cent the first area and 9 per cent the second area. In this case, it would be stated that the data indicate that a difference exists.

The proportion of times that a Type II error will be committed may be reduced to any desired level, for example, 20 per cent, by increasing the sample sizes so that statistical significance (R = 2) is attained at the observed difference which is equalled or exceeded 80 per cent of the time in repeated samplings. This means that only one time in five, when the populations are different by an expected amount, will an observed difference occur which is less than the value required for significance, and consequently, only one time in five will the existence of a population difference not be claimed on the basis of sample results.

To illustrate, it may be desired to reduce the frequency of making a Type II error to, say, one-fifth (20 per cent) of the time. The following calculations show how to determine the approximate number of animals in each sample required to recognize 80 per cent (i.e., 100 per cent − 20 per cent) of the time (instead of 50 per cent as before) a population difference as significant (at the 5 per cent level for a Type I error), allowing for the observed difference to fluctuate below as well as above the true value.

EXAMPLE

If true $P_1 = 10$ per cent and true $P_2 = 20$ per cent, what size of sample is needed from each of the two groups to show a significant difference between the observed p's with the probability of a Type I error = .05 and the probability of a Type II error = .20?

An approximate formula for the sample size is

$$(4) \quad n = \frac{(2.84)^2(P_1Q_1 + P_2Q_2)}{(P_1 - P_2)^2}$$

where 2.84 represents a constant appropriate to the above levels for a Type I and Type II error. P_1 and P_2 represent the proportion in Populations 1 and 2 which have the attribute being studied. $Q_1 = 1 - P_1$ and $Q_2 = 1 - P_2$.

Substituting we have

$$n = \frac{(2.84)^2\,(10 \times 90 + 20 \times 80)}{(20 - 10)^2} = 202$$

The wildlife manager will, thus, notice that about 200 elk need to be observed in each sample to reduce the probability of making a Type II error to 20 per cent.

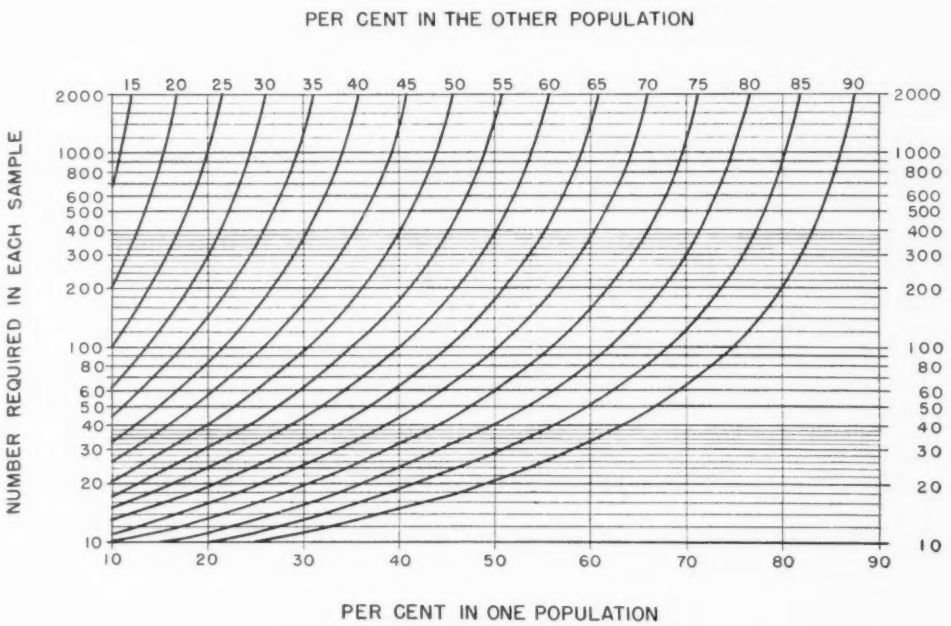

FIG. 2. Chart for estimating number of animals required for statistical significance between percentages. Probability of Type I error = .05. Probability of Type II error = .20.

Figure 2, constructed from data obtained from W. G. Cochran, gives estimates of sizes of samples needed to establish differences of various percentages with 5 per cent probability of a Type I error and 20 per cent probability of a Type II error. Similar charts could be constructed using values other than 20 per cent for the probability of making a Type II error.

How to Interpret Use of Charts

In the practical situation the investigator will have some idea about the proportions having the attribute being studied. In deciding which figure to use in determining the size of samples needed, he must consider the consequences of making a Type II error. For example, if the study represents the major project of the worker in terms of time, money, manpower, etc., he would be hesitant about accepting a 50 per cent chance of not being able to demonstrate a difference when one really exists. In such a situation he would refer to Figure 2 to see how many observations are needed to cut probability of a Type II error to 20 per cent. If his pre-experiment guess of population difference were true, he would be taking one chance in five that his sample results would not provide him with a significant difference. In the event that the number of animals required to meet these precautions is too large, a decision might be reached concerning some intermediate level of a Type II error (30 or 40 per cent) which might be satisfactory with respect to the protection provided, and also be within the means of the experimenter. To work at the 30 per cent level,

$(2.52)^2$ should be substituted for $(2.84)^2$ in equation (4); at the 40 per cent level, $(2.25)^2$ should be used. In some instances it may be necessary to set aside the experiment in favor of another project if the resources of the investigator do not permit a sufficiently powerful test, i.e., reduce the probability of making a Type II error to an acceptable level.

Suppose, for example, that a game commission will maintain its game-farm program if the results from the pheasant studies indicate that the survival of reared birds is "good." This decision would involve continuance of major activities, payroll costs, and so forth. It involves a definition by the commission as to what it considers "good" survival. Under these circumstances the investigation should be organized so that the possibility of committing a Type II error is low because so much depends upon the results.

On the other hand, Figure 1 will be applicable when the experimenter has a wide range of studies to complete and is, therefore, limited in the resources that can be expended on each of these projects. In order to run all his experiments and get an overall picture of his work, he may be willing to accept the 50 per cent risk of not picking up the true difference in an individual experiment. His results may tell him whether or not to continue on certain projects. Some of his observed differences, though not quite significant, may be sufficiently large to be of interest to the experimenter and may indicate need for a more extensive study. The direction of further work may thus be guided.

It should be emphasized that both charts are constructed so that the probability of committing a Type I error is 5 per cent. As stated earlier this is the level which is conventionally used in most work, however, there is no particular reason for assuming that this is always the appropriate level. The actual level used should be determined in the light of consequences following this type of error. Consider preparations for a gopher control program in which a poison is to be chosen for use in the project. A laboratory test is to be run to compare the effectiveness of a new poison against a standard which is currently being used. The test is to determine whether or not the new poison will replace the old. If the poisons are actually of the same potency, a Type I error (concluding that the new poison is superior to the old) will result in a program using the new poison instead of its equal, the old poison. This is not a serious error unless the old poison is considerably less expensive than the new. However, to commit a Type II error (failure to detect a difference when the new poison is superior) is of a more serious nature since it would result in continued use of the old poison, requiring a longer, more extensive and expensive campaign to attain the same results that could have been achieved more efficiently by the new poison. In such a situation it would be advisable to use enough animals in the laboratory test to make the probability of a Type II error low and not be very strict on the level of a Type I error. Consideration of the consequences of the types of error in a particular experiment may result in a reduction in the size of samples required and, therefore, in expenses as well. A monograph from which to estimate required sample size for levels of Type I and Type II errors from .001 to

.50 may be found in "Techniques of Statistical Analysis" by the Columbia University Statistical Research Group, McGraw Hill Book Company, New York, 1947.

CAUTIONS

The charts assume that the same number (n) is to be obtained in each sample. If one sample is not equal in size to the n required by the chart being used, it is not safe to assume that simply making $n_1 + n_2 = 2n$ will provide the needed number for statistical significance. It is best in such cases where n_1 does not equal the required number n given in Figure 1, to use the basic formula (1) in estimating what the number n_2 should be. When working with Figure 2, n_2 may be estimated by

$$n_2 = \frac{P_2Q_2}{\left(\frac{P_1 - P_2}{2.84}\right)^2 - \frac{P_1Q_1}{n_1}}$$

It is of utmost importance to remember that these charts are only for planning. The suitable calculations for determining statistical significance after the experiment is completed should be carried out by using Formula (1) for the ratio, R, and the actual observed data, and by consulting a table which will furnish significance levels for given values of R (Pearl, 1940: 480). An example of the use of Formula (1) is included here to demonstrate the manner of testing for significance of observed differences:

Suppose that in one area 127 elk were examined of which 18.1 per cent were yearlings and that in another area 94 elk were examined of which 11.9 per cent were yearlings. From Formula (1) we have

$$R = \frac{18.1 - 11.9}{\sqrt{\frac{(15)\ (85)}{127} + \frac{(15)\ (85)}{94}}} =$$

$$\frac{6.2}{\sqrt{(10.0 + 13.5)}} = \frac{6.2}{4.9} = 1.27$$

Since R is less than 2, it should be stated that the difference is not statistically significant.

Another point concerns the fact that the basic formula on which Figure 1 is based is not applicable in situations where the percentages are small, unless a very large number of animals are used; i.e., when either np or nq is small, say less than 10. To overcome this difficulty, one would be on the safe side if the following rules of thumb worked out by Dr. R. V. Rider were followed:

1. When the required n is less than 10, and hence, not indicated on the chart, use n = 10.
2. When the n is indicated on the chart but np (or nq) is less than 10, observe in each sample a number equal to one and a half times the n indicated by the chart.

In either of these situations the final test of the observed difference must be made by use of a so-called Yates' correction for continuity (Fisher, 1946, 92; Hill, 1950: 140) or by Fisher's exact method (Fisher, 1946: 96).

The approximate formula (4) presented in connection with reduction of the probability of a Type II error is most applicable for P values within the range of those given in Figure 2.

In using the figures, one should not be disturbed because n cannot be read with the same absolute (arithmetic) precision over the whole scale. It was previ-

ously indicated that the logarithmic scale was selected for n primarily to space the lines more conveniently, but the scaling is reasonable on other grounds as well. In planning an experiment it makes a considerable difference whether 60 or 100 rabbits are required, but it makes relatively little difference whether 760 or 800 need to be collected. In general, it is wise in reading n to round off the value on the upper side of what appears to be the "correct" value.

Lastly, the experimenter should remember that he has merely begun the analysis when he established the statistical significance of a difference between two sets of data. The point of real interest to the wildlife manager is the interpretation: What is the biological significance for the species?

We are indebted to Dr. R. V. Rider for statistical advice on this problem and to Professor W. G. Cochran for permission to use the data from which Figure 2 was constructed.

SUMMARY

Charts (Figs. 1 and 2) are presented which help the planning of experiments by indicating the approximate number of animals required in each sample to establish a difference in percentages as significant at the 5 percent (probability of a Type I error) level. The charts are constructed for two levels of Type II error (failure to ascribe significance to a real difference). Discussion of the two types of error, applicability of the respective charts, and several examples are also given.

LITERATURE CITED

FISHER, R. A. 1946. Statistical methods for research workers. Oliver and Boyd, Edinburgh and London, 10th ed. xv. 354 pp.

HILL, A. B. 1950. Principles of medical statistics. The Lancet Limited, London, 5th ed. ix + 282 pp.

PEARL, R. 1940. Introduction to medical biometry and statistics. W. B. Saunders Company, Philadelphia and London, 3rd ed. xv + 537 pp.

Accepted for publication March 23, 1953.

PHEASANT WINTER ROOSTING COVER PREFERENCE IN NORTH-CENTRAL COLORADO

L. Jack Lyon

Colorado Cooperative Wildlife Research Unit, Colorado A & M College, Fort Collins, Colorado [1]

It is axiomatic that good cover in proximity to food constitutes the best insurance against heavy winter losses in upland game-bird populations. Since the North American pheasant range coincides generally with the grain belt, winter food for these birds is usually plentiful. Cover, however, is frequently inadequate, especially as it affects food availability and provides protection against critical winter conditions. Thus, cover is the key to winter habitat, and to survival of breeding stock, over much of the pheasant range.

Fundamental in the role of pheasant winter cover is its relationship to roosting. Freezing, or more accurately, suffocation of birds, occurs when they are waiting out blizzard weather, and is most common in inadequate roosting cover (Miller, 1948; Brown, 1948). Other aspects of the roosting-cover problem appear to have been little studied.

Methods

During the winters of 1950–51 and 1951–52 study plots were established in all major cover types in north-central Colorado pheasant range. Where possible, these plots were square, 100 feet on a side; but in a few types, shape or scarcity of cover necessitated rectangular plots of smaller size. Fourteen such plots were checked 1 to 2 days after each snowfall, and at 7-day intervals when no snow was on the ground. Pheasant roost sites, as indicated by droppings, were counted and the droppings destroyed to prevent duplication in subsequent counts.

Permanent-cover plot locations were the same during both winters, but crop-type plots had to be relocated at the beginning of the second year. An attempt was made to establish all non-cultivated sample areas in such locations that adjacent cover would not affect pheasant use thereof; and crop-type plots were established well inside field borders so that fencerow cover would not unduly bias results. It should be recognized that varied terrain and other physical factors characterizing the 14 locations prevented absolute comparability in plot orientation.

Some variation in results may have been caused by differences in pheasant population densities, but since all plots were in one township, this factor was regarded as relatively insignificant. Weekly flushing of birds from some plots might have affected results, but this was

[1] The Colorado A and M College, the Colorado Game and Fish Department, the Wildlife Management Institute and the U. S. Fish and Wildlife Service, cooperating. Acknowledgment is made to Dr. Lee E. Yeager and to J. H. Berryman, Fish and Wildlife Service, for suggesting the problem, for counsel during the course of study, and for assistance in preparing the manuscript.

TABLE 1.—DESCRIPTIONS OF ROOSTING COVER STUDY PLOTS

Type	Main Cover Plants[1]	Cover Height, Inches[2]	Density, Stems per Sq. Ft.	Winter Use	Distance to grain-food, Yards
Riverbottom	Wild roses, snowberry, ragweed, *Kochia*, switchgrass, wheatgrass and cottonwoods	12 - 18	15 - 20	Pasture	440
Weed patch	Ragweed, Canada thistle, *Kochia* and yellow sweetclover	24 - 48	20	Uncultivated not pastured	500
Ditch banks:					
S. exposure[3]	Ragweed, yellow sweetclover, Russian thistle, wheatgrass, wild rye, cheatgrass, cattails, willows, cottonwoods	12 - 20	15 - 20	Uncultivated not pastured	80
N. exposure[4]	Yellow sweetclover, smooth brome, wild rye, cattails, willows	10 - 15	3 - 5	Uncultivated not pastured	80
Willow thicket[5]	Willow, horseweed and wheatgrass	48 - 84	5 - 7	Uncultivated not pastured	4
Cattail slough	Cattails, hardstem bulrush, switchgrass	36 - 40	6 - 9	Lightly pastured	4/150[6]
Dryland pasture	Blue grama, buffalo grass, threeawn, yucca, rabbitbrush	1	50	Pasture	35
Cornfields:					
Machine-cut	Corn	4	0.2	Idle	80
Hand-picked	Corn, some weeds	36	0.2	Idle or pastured	..
Alfalfa	Alfalfa	1 - 2	35 plus	Idle	30
Small grain:					
Irrigated	Barley or oats	3 - 4	25 - 30	Idle	..
Dryland	Wheat	15 - 20	15 - 20	Idle	..
Sugar beets	Sugar beets	0	0	Idle	20
Irrig. pasture	Saltgrass, blue grama, wild rye, wheatgrass	1 - 2	75 plus	Pasture	440

[1] Listed in order of abundance.
[2] Approximate average height.
[3] Included only 5,000 square feet.
[4] Averaged 2,200 square feet.
[5] Averaged 1,642 square feet.
[6] Slough bordered by grain in 1950 and by sugar beets in 1951.

likewise disregarded since all received the same disturbance. In plots which attracted large numbers of pheasants it was noted that birds often returned to cover almost immediately after the observer departed.

STUDY PLOTS

Description of the 14 plots is based on four major points of comparison: floral species, density of cover, height of cover, and land-use during the winter period (Table 1). Distance to the nearest waste grain (corn, small grain, beans) is listed.

PHEASANT ROOST SITES

Table 2 shows dates of field checks and number of pheasant roost sites recorded.

Of the 14 types, only two, the weed patch and the cattail slough, were found to be preferred roosting cover during both winters. Use of the weed type fluctuated with weather conditions, but was usually high during periods of deep snow and/or cold weather. A noticeable decline in pheasant use of this type occurred in December, 1951, when the area was used as a holding pasture for a flock of sheep. Use was resumed almost immediately after removal of the sheep, but did not become normal until late January. Roosting in the cattail-slough type remained fairly constant. After freezing of standing water, pheasants moved in from the surrounding area and remained until the slough thawed or was burned in spring. Because of the sheltering effect of cattails, ice, once formed, remained all winter.

TABLE 2.—PHEASANT ROOST SITES BY COVER TYPES

Type[1]	1950–51 Total Roost Sites (15 observations)	1951–52 Total Roost Sites (14 observations)
Riverbottom	2	0
Heavy weeds	150	120
Ditch bank; S. exposure	2	0
Willow thicket	30	0[2]
Cattail slough	11	41
Grain stubble—irrigated	0	0
—dryland	2	0

[1] Plots in which no roost sites or birds were observed have been deleted. These include northern exposure of ditch bank, dryland pasture, hand-picked and machine-cut corn, alfalfa, sugar beets and irrigated pasture.

[2] Lack of use of willow cover during 1951–52 was probably due to late fall burning of the study plot in that year.

Four other types—riverbottom, southern exposure of the ditch bank, willow thicket, and dryland grain stubble—were used occasionally, but did not appear to be important when the weather was such that good shelter was needed. Apparently these types were used in fairly open weather, but pheasants invariably moved into heavy weed patches, cattails, and unpastured riverbottoms, where shelter was more effective, during periods of low temperature and deep snow.

Where the river bottom was not grazed or burned, it offered a variety of food and cover unsurpassed by any other type. Winter pasturing and some fall burning reduced a large percentage of this cover to the barest minimum. The study plot of riverbottom was thought to be representative of the type as a whole, but because of differences in grazing and other land-use treatments, certain selected areas would have indicated a higher pheasant preference.

The southern-exposed ditch bank, although much like the weed area in general appearance, was not used as roosting cover. Several possible reasons for lack of use of this area were considered. A cold air pocket in the ditch along which the plot was established kept it cooler than surrounding country. The lower temperature, however, seemed to have no influence on use of this type by cottontails, which were common. Tracks of skunk, raccoon and cat were noted in the plot several times, but predators did not seem to be sufficiently abundant to affect either pheasants or cottontails. Schick (1952) found this avoidance of apparently good cover areas to be common among wintering birds on the Prairie Farm, Saginaw County, Michigan, but he could offer no explanation.

Use of the willow thicket indicated a fairly low pheasant preference for this type, but because the study plot was so small the data cannot be considered conclusive. In an area around Lindenmeier Lake, a private game refuge north of Fort Collins, willows are extensively used by pheasants for winter shelter. Pheasants' preference for willow thickets, especially where mixed with weeds and bordered by grainfields, is believed to be higher than indicated here.

Dryland grain stubble was the only cultivated type for which any value as winter roosting cover was recorded. In the main dryland-wheat regions, this type, although not particularly outstanding for shelter, may be the only cover available. Part of the reason for pheasant use here, always during mild weather, probably lies in the fact that harvesting (combining) misses enough grain to make food particularly attractive to the birds.

The eight remaining study types—dryland pasture, irrigated pasture, machine-cut corn, alfalfa, sugar beets, irrigated grain, northern-exposed ditch bank, and hand-picked corn—were not used as roosting cover during either year. The first five types were virtually barren after harvest, and the remaining three, although not completely barren, offered little shelter. Irrigated grain stubble was so short that, even when not covered by snow, little cover was available. On the ditch bank, cover was so thin because of lack of moisture and direct sunlight, that good shelter was not produced. Hand-picked corn offered no effective roosting cover due to the wide spacing of plants, but ample food was available here in the form of scattered grain.

Use of the weed patch indicated a decided preference by pheasants in all weather conditions. When deep snow and temperature below 15°F. occurred, the number of roost sites always ran above average for the type. When only light snow, or none, was present, the number of sites fluctuated without any distinct relationship to temperature. This scattering of data seems to indicate that, unless snow was present, the birds made no effort to reach the weed area before nightfall. Since deep snow and low temperature, especially in combination with strong wind, are the factors normally associated with winter loss in game populations, movement of birds to heavy weeds under these conditions indicates the merit of the type for winter roosting.

Position of individual roosting sites in preferred types showed an interesting

similarity throughout the study. Pheasants usually roosted without thick overhead cover, almost invariably choosing locations that would allow them to escape into the air without running. Preferred areas in weed and cattail types were those in which at least part of the cover had been laid over by heavy snows or livestock. In the willow thicket, pheasant use was almost entirely confind to small willows and weeds on the periphery of the stand.

Relationship of good cover to grainfields apparently had no effect upon pheasant preferences. The weed area was farther from grain than any other plot, yet was preferred for roosting purposes over all other types.

CONCLUSIONS

Close examination of each of the 6 types for which some preference was indicated reveals only one major point of similarity—vegetation was always in excess of 15 inches in height. Density in these plots ranged from 6 to 30 stems per square foot, and food was both scarce and abundant. Obviously neither low stem density nor abundant food appear to determine pheasant use of roosting cover; instead, it appears that cover can be judged for its roosting value on the basis of height alone.

In habitat improvement programs, especially on agricultural areas similar to north-central Colorado, it is suggested that herbaceous cover of some type be provided in addition to woody growth. On the basis of results given here, weeds serve this function perfectly, but where the maintenance of weed cover is impractical, clover, sudan grass, or other may be substituted. Most habitat-development projects, especially on the Great Plains, appear to be designed as windbreaks and, as such, include little ground cover suitable for roosting purposes. To attain maximum value for pheasants, herbaceous species should be established along the periphery of the major planting. Such cover should stand at least 15 inches high under all weather conditions, and should be open overhead.

SUMMARY

Fourteen winter-cover plots on northern Colorado farmland were examined for pheasant roost-sites at about weekly intervals during the winters of 1950–51 and 1951–52. The number of pheasant roost-sites on each plot was recorded and these numbers were used as an indication of the relative pheasant preference.

Heavy weeds and cattails were found to be highly preferred winter roosting cover types. In addition, limited use was made of riverbottom, ditchbank, willow, and dryland grain stubble.

Comparison of weather conditions with pheasant use in the weed type showed that the birds moved into this cover during periods of severe snow and cold. Consistency of such use indicated the pronounced merit of heavy weeds for roosting purposes.

In the six cover types used by pheasants for roosting, only one point of comparison could be found—that of height. Despite variation in other factors, all preferred vegetation was over 15 inches tall.

In future habitat development programs, consideration should be given to the inclusion of herbaceous cover on the periphery of the major planting. Species used should stand at least 15 inches high

under all weather conditions and should not form a close-knit overhead structure.

LITERATURE CITED

BROWN, E. K. 1948. More pheasants from Federal Aid. Colo. Cons. Comments 10(8): 3–4.

MILLER, W. L. 1948. Pheasants killed by blizzard. N. Dak. Outdoors 10(9): 4–6, 10, illus.

SCHICK, C. 1952. A study of pheasants on the 9,000-acre Prairie Farm, Saginaw County, Michigan. Mich. Dept. Cons., Lansing. 134 pp., illus.

Accepted for publication March 26, 1953.

STATUS OF BEAVER IN WEST VIRGINIA [1]

R. Wayne Bailey

West Virginia Conservation Commission, Marlinton, W. Va.

The original beaver population of West Virginia was probably exterminated by 1825. The first colony occurring in the state in the twentieth century was found in Hampshire County in the fall of 1922. Thus, for a period of about one hundred years the species was not a part of the fauna of the state. Restocking of beaver began after the severe drought of 1930 and during the period 1933–1940, when sixty-four beaver were released in various parts of the state. Their increase, under complete protection, was rapid and by 1947 much of the area of the counties of Pocahontas, Randolph, Tucker and Grant had been occupied (Swank, 1949). The first open season occurred in 1948 with only forty beaver reported taken by over one hundred trappers operating under rather strict controls.

By the fall of 1951 most observers were of the opinion that a definite shift or change had occurred in the amount of territory occupied by beaver. The population was apparently dwindling in some areas and increasing in others. Accordingly, a decision was made to conduct a state-wide survey on which to base further management plans.

METHOD OF CENSUS

The census was conducted by: (1) foot travel, (2) airplane, and (3) verbal and written information received from persons familiar with particular sections of beaver range.

Information on the major portion of beaver colonies was supplied by Conservation Officers (several of whom knew their counties well enough to supply all of the information received), other Conservation Commission personnel, trappers, raccoon hunters, landowners, and

[1] Contribution from Federal Aid in Wildlife Restoration Act, Project 30-R, West Virginia. The writer is indebted to many persons, employees of the Conservation Commission and others, who cooperated in making this study possible. Special credit is due John Gill of the Game Division staff of the Conservation Commission of West Virginia who aided greatly in expressing and interpreting population and rate of increase data. C. O. Handley, Chief of the Division of Game, and Frank Johnson, P-R Coordinator, gave kind supervision throughout the course of the project.

others. Nearly all of the colonies were verified by more than one informant. Errors that appear in this method came as a result of colonies that had been seen one or two years ago instead of in the fall of 1951. Undoubtedly, there were also colonies that were missed.

Location of each colony was indicated on a United States Geological Survey map.

A colony was considered as one having an occupied house or lodge or evidence of young beaver. Non-colony beavers were indicated by open circles with the number believed to be at each location placed within the circle. In many instances the number represents the number of beaver actually observed at one time. In other cases it represents an estimate based upon the amount of "sign" or "cutting" in the vicinity.

Swank (1949), using an index of 5.3 beaver per colony, and allowing an additional 20 per cent for bank beaver, determined West Virginia's beaver population in 1947 as 2,143 animals.

Each colony was assigned a population value of five beaver. This figure was used, somewhat arbitrarily, for lack of anything better, since a change in index value undoubtedly has occurred since Swank's survey in 1947. Swank was censusing untrapped beaver while the 1952 census was preceded by four seasons of rather intensive trapping, two of them state-wide with a few local exceptions.

On larger streams where frequently neither dams nor lodges are built, presence of beaver at a given location was counted as a colony provided there was evidence that a family had been reared at that location.

Thus, in the manner outlined, beaver on all streams were tallied either as colonies or as strays.

Census Results and Rate of Beaver Increase

The 1952 census results show a total of 557 beaver colonies and 314 strays, giving a final tally of 3,119 beavers. Thus, the increase in four years was 976 beavers, 45 per cent, or an average annual increment of 11.3 per cent. Twelve counties reported beaver in 1952 that had no colonies in 1947. The population decreased in three counties.

It will be noted in Figure 1 that the total occupied beaver range in 1952 approximately doubled in area the occupied range reported by Swank in 1947. Present occupied range exceeds the "potential" range as it was listed by Swank. Not much space exists for further expansion of range of beaver in West Virginia.

Cook (1943), Bradt (1947), and Swank (*op. cit.*) estimated that the beaver reproduces at a rate of fifty per cent annually, but used the figure 33-1/3 per cent to make allowance for natural losses. It is observed that the present

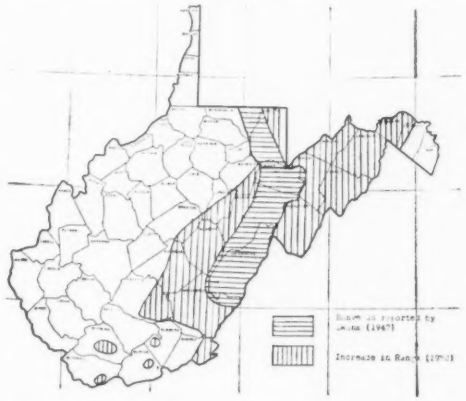

FIG. 1. A comparison of occupied beaver range in 1947 and in 1952.

population is sufficiently higher than in 1947 to indicate that annual increase is greater than 33-1/3 per cent (Table 1). In fact, after making the necessary allowances for trapping drain, it is found that annual increase is nearer forty per cent.

The 45 per cent increase in beaver occurring since 1947 took place, for the most part, in 1948 when less than 6.3 per cent of the population was harvested by trappers. Estimated per cent harvested in 1952 was 25.1. This does not include losses other than the reported trapping take.

In Table 1 an arbitrary ten per cent was added to the trapper take to allow for crippling losses, illegal kills, and other factors. If this table is representative, it appears that the beaver in West Virginia is reproducing at a rate of about forty per cent annually and that the beaver population is being controlled almost entirely by trapping. Apparently, population has been about stable for the past three years. Also, it appears that an annual trapping take of 750 to 800 will maintain the beaver population at about its present level. There are, of course, counties and areas where the take has been insignificant and continued increases in such areas will occur. Offsetting this will be a continued decline in other areas, particularly on the Monongahela National Forest.

It would also appear from the above that total loss of beaver, other than reported take, amounts to between ten and twenty per cent annually. The majority of these losses are believed to result from illegal shooting. Occasionally a beaver is killed by an auto or by dogs. Losses other than those caused by man are thought to be definitely minor.

ESTIMATE OF AGE RATIO BY PELT SIZE

Apparently, pelts of beaver kits are generally less than 54 inches (width plus length). However, there is an overlap between large kits and small individuals in their second year; thus, separation of beaver into age classes on the basis of pelt size is admittedly not a precise method of age determination. Pelt measurement, though, can no doubt be used to determine roughly the proportion of young in the population during the time of the trapping season.

When fifty-inch pelts and smaller are counted as kits, the following is noted for the years 1951 and 1952:

TABLE 1.—COMPARISON OF ESTIMATED WINTER BEAVER POPULATION AND TRAPPING DRAIN, BASED ON A FORTY PER CENT RATE OF INCREASE, FOR THE YEARS 1947 TO 1952

Year	(1) Winter Population	(2) Trapping Drain	(3) Spring Pop. (1–2)	(4) 40% Increase (3 x .40)
47–48	2140	150	1990	800
48–49	2790	640	2150	860
49–50	3010	900	2110	840
50–51	2950	780	2170	870
51–52	3040	860	2180	870
Total Trapping Drain	3,530		Total Increase	4,240

Year	Total Pelts Taken	No. Pelts 50″ and less	Per cent Kits
1951.....	713	274	38
1952.....	784	248	32

Since a small percentage of kit pelts probably measure more than 50 inches, total number of kits taken in the 1951 and 1952 seasons was probably slightly higher than shown. Taking this into consideration, the previous estimate of an annual increment of about 40 per cent is upheld by pelt-size figures.

Percentage of kits appearing in the reported kill could be expected to be smaller than actually exists in the population because of the following: (1) kits may travel less widely during the trapping season than do older beaver; hence, the number trapped might not be representative; (2) solitary bank beaver, which are generally not kits, are more easily taken than are colony beaver and their proportion in the take might also not be representative and (3) some of the better trappers, because of the low value of kit pelts, refrain from trapping near beaver colonies in order to reduce the possibility of capturing kits.

Beaver Harvest

In 1952, beaver harvested on a watershed basis varied from 0 to 100 per cent of the censused population. Total value of the 784 beaver pelts taken by 275 successful trappers (those catching at least one beaver) was $9,329.60 and represented an average return of about $34.00 per successful trapper or $11.90 per pelt. The figure of $34.00 does not, of course, represent total profit. All except thirteen persons who obtained beaver trapping licenses reported having trapped one or more beaver. A license is not required of *bona fide* landowners or tenants trapping on their own lands.

In addition to beaver pelts secured, the same trappers, while trapping for beaver, took from the vicinity of beaver colonies a total of 502 muskrat and 155 mink. These totaled $3,078.00 in estimated value and represented thirty-three per cent of the value of beaver pelts taken. The successful trapper reported taking an average of 2.8 beavers, 1.8 muskrats and .56 mink. The ratio of mink to muskrat was 1: 3.25.

It should be stressed that the reported muskrat and mink take represents animals taken by successful beaver trappers during the beaver season only. Undoubtedly a much larger number of muskrats and mink than that reported here are taken from the vicinity of beaver colonies prior to opening of the beaver season.

If it be assumed that the 3,119 beavers in the State during the 1951–52 season occupied 600 acres of land area (one acre per colony), average monetary return per acre was $15.55. Adding the muskrat and mink values to this gives a return of about $20.00 per acre. It should be considered that fur prices in 1952, particularly beaver, were the lowest in years.

Since 1950 the number of beaver trapping licenses sold in West Virginia has declined, except for a slight increase in 1952. The year 1950 was the peak in regard to number of licenses sold (327) and number of beaver trapped (821). Since that time, number of beaver harvested has remained relatively high while number of licenses sold dropped from 327 in 1950 to 285 in 1951 and increased slightly to 288 in 1952. Two reasons may be advanced for this: (1) Those interested in beaver trapping are

becoming more skilled and (2) weather conditions since 1950 have been favorable for trapping of beaver during the open season.

BEAVER ON PUBLIC LANDS

Of the more than 1,000,000 acres of public land in West Virginia, only lands of the Monongahela National Forest (about 800,000 acres) support an appreciable number of beaver. A minor number of beaver occurs on the 125,000 acres of state-owned land and has, as a result of the small number, presented no management problem.

The United States Forest Service and the West Virginia Conservation Commission, under a cooperative agreement, conduct a game management program on Monongahela National Forest. Twelve wildlife managers residing on the forest census the beaver population each fall and the figures derived are used in establishing the number of trapping units that are leased to trappers the following open season. Number of trappers allotted per unit is determined by estimated number of beaver on that unit.

The wildlife managers in the fall of 1951 estimated a total of 865 beaver on Monongahela National Forest. Thus, of the State's total of 3,120 (approximately 600 colonies), 28 per cent were in existence on the Monongahela. Several years ago most of the beaver in West Virginia occurred on this National Forest. The percentage of the State's total occurring on Monongahela National Forest is diminishing each season.

During the four-year period covered in Table 2, average winter population of beaver on Monongahela National Forest was about 950 which we can round off at 1,000 (200 colonies), since

TABLE 2.—NUMBER OF BEAVER REMOVED EACH TRAPPING SEASON ON MONONGAHELA NATIONAL FOREST

Year	No. Beavers Trapped	Estimated Population	Per Cent Trapped
1948.....	40	?	..
1949.....	264	885	30
1950.....	436	1200	36
1951.....	275	830	33
1952.....	275	865	32
Total.....	1290		32.5 (ave.)

population estimates were undoubtedly conservative. If we allow an "occupied territory" of one acre for each colony of beaver, average number of acres occupied each season was 200, representing three-one-hundredths of one per cent of the forest's total land area of more than 800,000 acres

A total of 1290 beaver was trapped on Monongahela National Forest from 1948 to 1952. They averaged about $20.00 each and represented a total of $25,-800.00 to the successful trappers.

During the last four trapping seasons, number of beaver harvested on the National Forest has varied from 29 to 36 per cent of estimated populations with an average of 32.5 per cent. The take on the National Forest in 1952 exceeded the State's average take (25.1 per cent) by seven per cent. Fall beaver population on Monongahela National Forest declined in 1951 when trapper-take of the preceding season equaled 36 per cent of the estimated population. Cause of the decline may not have been due entirely to trapping as some emigration may have occurred and productivity may have declined because of range deterioration.

Apparently, about 30 per cent of the

beaver population can be removed each season and a static number maintained. This makes allowance for an additional illegal kill and natural loss of about ten per cent.

With the experience trappers have gained in recent years, beaver population on Monongahela National Forest, as a whole, will probably continue to decline as it has since 1950. Owing to the fact that the beaver may have increased beyond the ability of food supply to sustain them, the population might have declined anyway. It is probably true that, when the season first opened in 1948, trapping regulations were too restrictive to allow trappers to harvest the number of beaver that was available for havest. From 1950 to the present, with better trappers afield, more favorable weather and a relaxation of trapping restrictions the take was between 25 to 40 per cent, or much closer to what it should be.

In view of the decrease of the beaver on Monongahela National Forest during the past few seasons, careful attention should be given the matter of establishing trapping units in order to assure: (1) a harvest not exceeding 30 per cent, (2) each trapper a reasonable opportunity to secure his allotment of four beaver, and (3) a minimum of expense in securing trapping permits and carrying out harvest operations.

It is recommended that a minimum of two active lodges be allotted per trapper-unit. This, ordinarily, would mean that approximately ten beaver would exist on each unit. In theory, a trapper taking his limit of four beaver would have reduced the population by 40 per cent, the allowable maximum. Actually, on an extensive area, trappers would average close to three beaver each; thus, the optimum harvest of 30 per cent would be achieved.

In establishing trapping units on larger streams where food piles are frequently washed out or where a large proportion of the beaver population may consist of "bank beaver" it is more difficult to assure adequate seed stock than is the case with beaver living in ponds. Therefore, more care must be used in delineating units on larger streams.

Beaver in ponds are much more difficult to trap because of ice conditions and the fact that their food piles make it unnecessary for them to leave the water. Bank beaver must leave their burrows to secure food even during severe weather.

Owing to the sharp decrease in value of beaver pelts in recent years, there is a possibility that interest in trapping of beaver may decline to the level where trapping, as currently controlled, may not be adequate for keeping the beaver population at a desirable level. Should such a condition arise, a further relaxation of trapping regulations, or an increase in number of beaver allowed per trapper, will be necessary.

SUMMARY AND CONCLUSIONS

1. Foot travel, airplane flights over remote areas, and contact with persons familiar with particular sections of occupied beaver range were employed in conducting the 1952 beaver census.

2. A total of 557 beaver colonies and 314 strays, tallying 3,119 beaver was recorded. This represents an increase of 45 per cent since 1947.

3. All of the beaver habitat listed by Swank in 1949 as "potential" is now occupied. The number of beaver has in-

creased in twenty-one counties and decreased in three since 1947. No more space exists for further expansion of beaver range in West Virginia.

4. Most of the increase in beaver since 1947 took place in 1948 when less than 6.3 per cent of the estimated population was harvested.

5. Beaver are apparently reproducing in West Virginia at a rate of about 40 per cent annually.

6. At present, the beaver population is being controlled almost entirely by trapping and by illegal shooting.

7. On a watershed basis, beaver harvested in 1952 varied from zero to 100 per cent of the censused population.

8. There were 275 successful trappers in 1952. They harvested 784 beaver. All except 13 persons who obtained beaver trapping licenses reported having taken one or more beavers.

9. Successful beaver trappers took an average of 2.8 beaver, 1.8 muskrat and .56 mink during the beaver trapping season.

10. During the 1952 beaver trapping season, 557 beaver colonies brought an average total fur return of $20.00 per acre of stream bottom occupied by beaver.

11. Total value of the 784 beaver pelts harvested in 1952 equaled $9,329.-60, or an average of $11.90 each. The 502 muskrat and 155 mink taken from the vicinity of the beaver colonies during the beaver season brought an additional estimated $3,078.00.

12. About 28 per cent of the State's beaver are on Monongahela National Forest. These occupy about .03 per cent of the forest's land area of more than 800,000 acres.

13. During the last four trapping seasons 1,290 beavers have been harvested from the Monongahela National Forest. They represent a return of $25,800.00 to the trappers.

14. The 275 beavers taken on Monongahela National Forest in 1952 represented a harvest of 32 per cent of the estimated population. The harvest for West Virginia as a whole amounted to about 25 per cent of the censused population.

15. The beaver population declined on Monongahela National Forest in 1951 when trapper-take of the preceding season equaled 36 per cent of the estimated population.

16. Trapping units on state and national lands should be regulated to harvest 25 to 30 per cent of the beaver population each year.

LITERATURE CITED

BRADT, G. W. 1947. Michigan beaver management. Game Div., Michigan Dept. Conservation, Lansing, Mich. 56 pp.

COOK, D. B. 1943. History of a beaver colony. Jour. Mamm. **24**: 12–18.

SWANK, W. G. 1949. Beaver management in West Virginia. Div. of Game, Conservation Commission of W. Va. 65 pp.

Accepted for publication April 3, 1953.

APPARATUS FOR THE STUDY OF INCUBATED BIRD EGGS

Harold C. Hanson

Illinois Natural History Survey, Urbana, Illinois

In recent decades, nesting studies of game birds have been subjected to extensive investigations. Often, however, the results of these studies have not seemed commensurate, either qualitatively or quantitatively, with the effort involved. Because field studies usually demand considerable time, often with only limited findings in prospect, it is important that as much basic information as possible be obtained from each series of observations. This may mean approaching a study with a fresh viewpoint or with more adequate instruments that will permit the gathering of new or more precise data. With this thought in mind, the writer developed an egg volumeter and a portable egg candler. While egg candling no doubt dates back hundreds of years, an adequate device for use in the field does not seem to have been developed. In addition to these instruments, which are described below, a method of photographing incubated eggs by transmitted light was also developed to provide photographs for comparison in estimating more accurately the incubation stage of candled eggs. Photographs have been taken of the day by day development of the eggs of the mallard (*Anas platyrhynchos*), wood duck (*Aix sponsa*), bob-white quail (*Colinus virginianus*) and mourning dove (*Zenaidura macroura*) which greatly increase the usefulness of an egg candler in studying these species. These photographs will appear elsewhere, but for those who may be interested in obtaining serial photographs of the development of the eggs of other species, the techniques used are described.

Uses of an Egg Volumeter and Volumetric Data

Mathematical formulae may be employed to calculate the volume of eggs from measurements of their width and length (Worth, 1940). These formulae only approximate egg volumes, as they do not take into consideration all inter- and intra-specific variation (Preston, 1953). Moreover, these formulae are comparatively difficult to use. Weight may be used as a measure of egg size, and if necessary, may be interpolated to egg-volumes if the latter value would be more useful (Barth, 1953). In either case, it is desirable to weigh the egg when fresh or during the first few days of incubation, as the weight of the egg decreases as embryo develops and air sac enlarges. Consequently an apparatus, simple to operate, which could be used to determine egg volumes by direct measurement, would have certain advantages over the above two methods.

What intra-specific relationships can egg-volume data be expected to show? Kendeigh (1941) has correlated egg size (weights of fresh eggs) in the house wren (*Troglodytes aedon*) with temperature, the largest being produced when temperatures were between 57°F. and 72°F., smaller eggs being produced in

early spring when temperatures were low, and the smallest of all in July when temperatures were high. An adequate series of egg volumes should more clearly indicate differences in egg sizes between subspecies of different size. Although not racially separated, an investigation of egg sizes would probably show that the small bob-white quail of Florida and Texas lay smaller eggs than their relatives in the northern states.

A study of the volumes of an adequate series of eggs of the mourning dove and other wild doves and of wild pigeons in relation to the sex of the young produced might give some additional insight into the relationship between egg size and sexuality in this family of birds. From his studies of various crosses of ring-doves (*Streptopelia risoria*) Riddle (1917) has stated that egg yolks of smaller size, high water content, and smaller energy content are correlated with maleness; egg yolks of larger size, lower water content, and greater energy content are correlated with femaleness in the offspring. He further reports that in the ring dove, the amount of energy stored in the egg yolk is least in the eggs of winter, "that is, in those which produce an excess of males; it is greatest in the eggs of summer, that is in those which produce an excess of females (Riddle, 1938)." The yolk of the domestic hen egg is reported to show the least seasonal fluctuation of all egg parts; in winter it is proportionately at its smallest; at the approach of the breeding season when total egg weight and the actual amount of albumen and shell have diminished, its absolute increase in size is at a maximum. In summer, the former have decreased proportionately and actually while the yolk remains the same size or becomes only slightly smaller (Romanoff and Romanoff, 1949).

If yolk content and egg size are related to sex determination in the pigeon, a study of egg size in the mourning dove might also be expected to show some relationship between egg size, time of season produced, and sex of offspring. It was recently found that unisexual broods are apparently the rule in mourning doves (Kossack and Hanson, 1953) although the expected 1–2–1 brood sex ratio is found in pigeons (Levi, 1941). The first egg laid (determined by candling) of a mourning dove clutch is readily distinguished visually from the second egg of the clutch by its comparatively oval shape; in almost all cases the second egg is longer and more pointed. These apparent differences are supported by measurements: the first egg (A) laid of 28 clutches averaged 27.5 x 21.4 mm.; the second egg (B) laid averaged 28.3 x 21.4 mm. The difference between the first and second egg is principally one of length (.8 mm.) and shape, as averaged volumetric measurements of 10 clutches indicate no difference between the first and second eggs of a clutch (A or B = 6.6 cc.). Volumetric measurements fail to reveal a significant difference between eggs laid in May and eggs laid in June, although linear measurements of first and second clutches suggest that the eggs of second clutches may average slightly larger than those of first clutches.

MEASUREMENT OF EGG-VOLUMES

Crude volumetric determinations can be made by merely submerging an egg in a graduate partially filled with water. For example, if a mourning dove egg is placed in a partially filled 100 cc. graduate, which is approximately of the

same diameter as a dove egg, the resulting measurement is accurate only to the nearest cc., which is obviously inadequate since the average mourning dove egg has a volume of only 6 cc. The egg volumeter shown in Figure 1 improves the accuracy of such measurements. This instrument consists of a section of a regulation titration burette with a stopcock welded to its upper end. The lower end is fused to a ground glass joint, the inserted portion of which has been sealed off to form a plug. The egg is held by spring tension between two small hoops of phosphorous bronze wire mounted on a brass rod which in turn has been attached to the inner end of the ground glass plug with ferrule cement.

In operation, the volumeter is turned upside down and filled with water so that when righted the water will be somewhat above one of the lower graduations on the burette. A reading is taken with the ground glass plug tightly in place and after the stopcock has been opened momentarily to equalize the air pressure in case compression has oc-

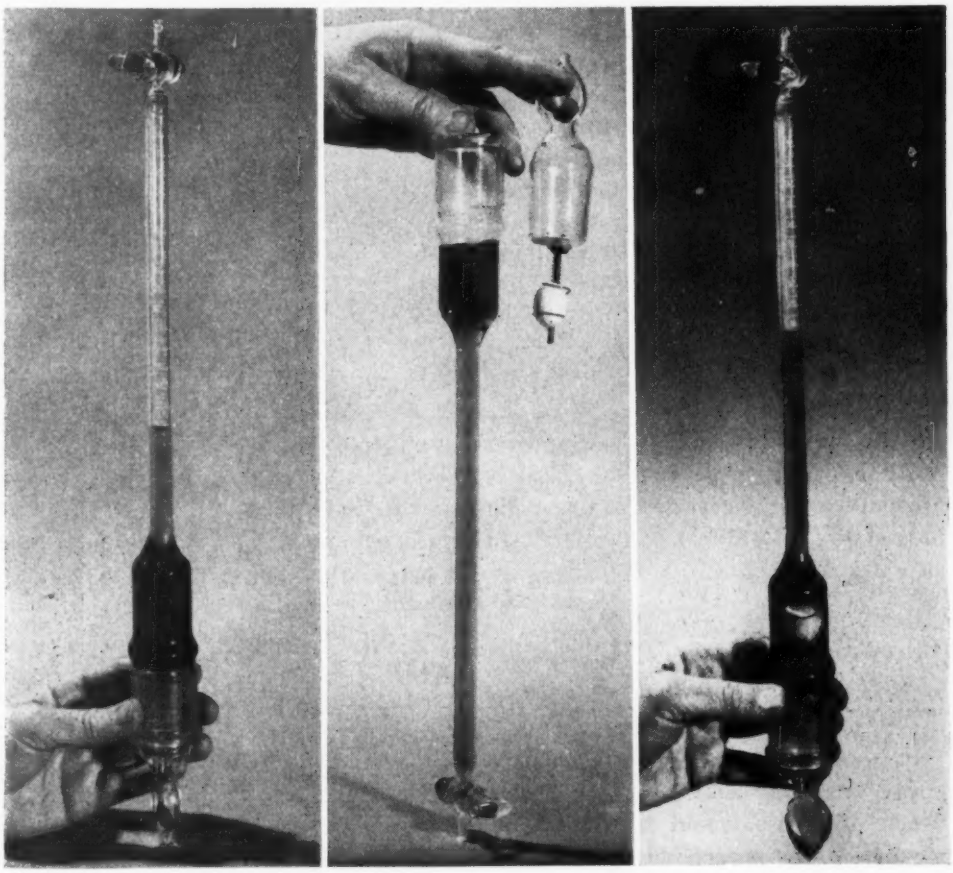

FIG. 1. A glass egg volumeter and method of use.

curred when the plug was inserted. The volumeter is then inverted, the plug removed, and the egg inserted between the hoops. The plug is then again put in place, the volumeter reverted to upright position and a second reading taken. The difference between the two readings is the volume of the egg, accurate to about .1 cc.

Several precautions should be observed in carrying out the above operation. The burette portion of the tube should be clean so that a water film will not adhere to its sides. Five to ten seconds should elapse before taking each reading in order to permit all water to drain down from the unfilled portion of the burette. The stopcock and ground glass plug should be well greased with stopcock grease. When the plug is removed for insertion of the egg, it should be held directly over the open ground glass joint so that any water drops falling from it will not be lost. Before taking the final reading, the stopcock should again be momentarily opened to release any compressed air.

To obtain an unbiased test of the accuracy of the egg volumeter, a student assistant made repeated measurements of the same egg. The results of 12 measurements in which an attempt was made to read the burette to 1/100 of a cc. are as follows: av. 5.29 (5.20–5.48), S. D. = .08, V. = 1.51.

USES OF A PORTABLE EGG CANDLER

Field workers often find it inconvenient to visit some nests more than once. For these nests, information can be obtained with the use of an egg candler which otherwise would be missed. If incubation has progressed more than a day or two, infertile eggs and those containing dead embryos can be readily detected. If a nest is visited when the eggs are in a late stage of incubation, data on the number of dead embryos will be more complete and accurate than those obtained earlier. Two peaks in mortality during embryonic life are known to occur: One during the early stages of incubation is presumably due in a broad sense to failures in respiratory adjustment; the second during the late stages of incubation is related to inadequate water supply (Riddle, 1930). According to Riddle, these respective mortality peaks occur in the wild dove on the second and during the last two days of incubation, the first peak being the highest. Although some losses may occur at pipping time due to failure of the young to break free from the shell, a candler usually enables one to determine with considerable accuracy the probable outcome of a nest, providing the incubation period is terminated normally.

The primary purpose of candling eggs is, of course, to ascertain age of embryos, and through examination of many nests, to accurately and efficiently determine the chronology of the nesting season. Candling also enables the investigator to anticipate the date of hatching so that return visits, if desired, can be made on the appropriate dates and the final outcome of the nest more readily determined. In the case of altricial species such as the mourning dove, the visit can be so timed that the young can be banded just before they leave the nest.

PORTABLE EGG CANDLER

The portable egg candler shown in Figure 2 had its origin in a crude model built in 1948. Reduction in size and weight to lowest practical limits and in-

creasing efficiency of the lighting and power source were the main problems in designing the candler for field use. The model finally developed fills the requirements of the field worker in most respects and will handle all eggs up to the size of that of a Canada goose. Smaller models can be developed, but in most cases it will probably be found that in doing so the operator will be handicapped visually and the efficiency and versatility of the candler in handling eggs of different sized species will be reduced.

The present unit employs two medium-sized flashlight batteries for the power source. These batteries are wired in series with each other and in parallel with the light bulbs. The latter may consist of either 2.8-volt flashlight bulbs held in pilot light sockets or Welch and Allyn otoscope bulbs that are screwed into threaded holes in a small piece of brass (Fig. 3). In either case three bulbs are employed, the outer two controlled by one micro-switch and the center one controlled separately by a second switch (Fig. 3). The addition of a third light to the unit adds little if any to the total over-all illumination and a single light burns almost as brightly as two; however, a better distribution of light results from the use of two, and the third is of value as a spare. Flashlight bulbs and pilot light sockets constitute a cheaper unit, but because of their size, the light is spread over a larger area. Penlight-type bulbs with fused-in lenses are advantageous as they concentrate light at the egg surface. Otoscope bulbs are fairly expensive, but as they are

FIG. 2. A portable egg candler designed for field use. The box is constructed of aluminum.

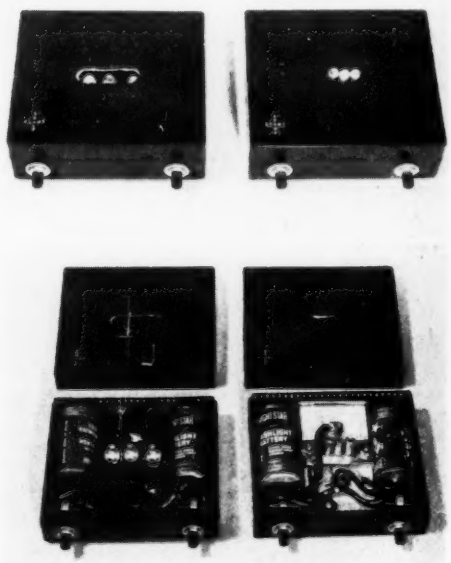

FIG. 3. Two types of power units for use with a portable candler.

small they produce a more concentrated light. As these bulbs are rated at 2.4 volts, they burn above rated capacity when 1.4 volt batteries are wired in series; hence, they burn somewhat brighter than do two-cell flashlight bulbs which have a slightly higher voltage rating. It has been the writer's experience that the life of otoscope bulbs (which have a rated life of ten hours and easily last a season of use) is not shortened enough to outweigh the advantage of burning them at full battery voltage.

The entire power unit is housed in a bakelite microscope slide box designed to hold 25 slides. A box of this type is of such ideal size and durability for the purpose that a better improvisation would be difficult to achieve. A wiring diagram of the power unit installation is shown in Figure 4. If a candler is desired primarily for use in studying duck eggs or eggs of similar size and opacity, it is suggested that two power units be used; the uppermost to house two batteries, a small reflector and a 6-volt flashlight bulb; the lower to contain three batteries connected in series with the top unit by a plug and socket arrangement.

A reading lens, 2 x 3-7/8 inches, is installed in the center portion of the candler about five inches above the power unit. A simple meniscus lens of this type not only has the advantage of enlarging the image, but also enhances its quality. A green filter, installed above the reading lens, increases the contrast of the embryo and associated organs, but is not a requirement for effective use of the candler.

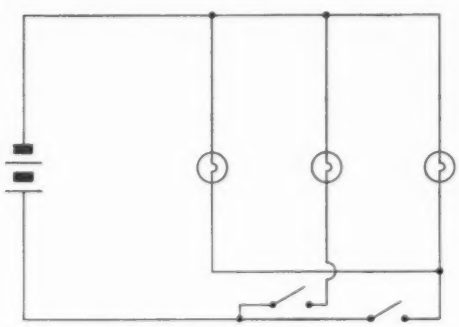

FIG. 4. Wiring diagram for candler power units.

When an egg is to be studied, it is placed snugly in a hole of appropriate size made in a pad of soft sponge rubber, 3/8 to 3/4-inch thick, depending on size of egg. These pads, cut to fit the internal dimensions of the candler and inked black or covered with black cloth, effectively mask out all light except that passing through the egg. The egg itself can be sometimes adequately manipulated with the forefinger through a hole cut in the door (Fig. 2).

The accuracy with which the incubation stage of an egg can be determined depends on a number of variables: incubation period, size of egg and shell opacity. The latter is, of course, dependent on such factors as shell thickness, color and markings. The stage of incubated mourning dove eggs can be usually determined to the day through the first six days and for the last two days of incubation, within a day for stages from the seventh day to the eleventh day. Stages of larger eggs can be usually determined to the day during the first third of incubation, usually within a day for the next few days, while during the last half of incubation stages can only be approximated from size of air sac. In any event, it should be remembered that if incubation is erratic, dating back from the determined egg stage will not necessarily give the actual date an egg was laid.

PHOTOGRAPHY OF INCUBATED EGGS

The use of a candler would be limited if each worker had to learn by experience the appearance of embryos, as seen through the shell, at various stages of incubation. Although notes and sketches of the various developmental stages would be helpful, it is believed that a series of day-by-day photographs of incubated eggs can best show the criteria by which age of embryos can be determined. A photograph of a wood duck egg on the sixth day of incubation is presented (Fig. 5), to show a product of the photographic procedure described below.

The following problems must be dealt with in photographing bird embryos in the shell by means of transmitted light: Except for transmitted light, the photographs must be taken in complete darkness; the light source used must be strong enough to penetrate the egg so that the embryo stands out in shadowed relief; the light must be of an instantaneous nature in order to "stop" movement of the embryo; a fast, color-sensitive film must be used in combination with a filter so that the embryo and its associated structures will register on the negative with adequate contrast.

The apparatus shown in Figure 6 and the following procedures were used in meeting the above problems. By housing the camera, egg, and light source in a light-tight box, alignment of all three components was assured. The camera used, a 9 x 12 cm. pack and cut film style, was mounted on an adjustable sliding rack to facilitate regulation of

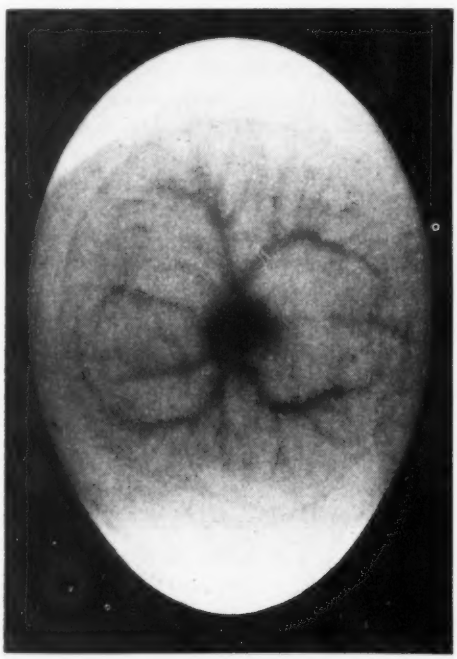

FIG. 5. A wood duck egg photographed on the sixth day of incubation.

FIG. 6. Dark box and method of photographing incubated eggs.

image size. Supersensitive panchromatic film was used because it is both fast and highly color-sensitive. This film alone, however, will not register with adequate contrast, the whitish, yellow, orange and red hues of the various structures of an egg when illuminated with transmitted light in early stages of incubation. After experimentation with various filters, it was found that a dark green filter (Eastman Wratten B, Number 58) produced a negative image having the greatest contrast.

As in the case of the egg candler, it was found advantageous to use a simple meniscus lens between the camera lens and the egg in order to increase size and quality of image. For photographing, the egg was mounted in a hole in a mat of sponge rubber, cut so that the edges of the hole would fit snugly around the sides of the egg, thereby excluding stray light from below. The egg and rubber mat were supported by a piece of glass covering a hole cut in a plywood partition placed between egg and camera.

A stroboscope flash gun and the conventional batter-type flash gun were used as light sources. A "strobe" light and midget flash bulbs were adequate to illuminate eggs during the first few days of incubation; for later stages larger flash bulb sizes such as press 40's, #50 and #3 were used.

Near the mid-point of incubation the embryo flexes and moves about within the egg. To illuminate the egg prior to making the exposure and to assure exposing the film when the embryo is against the under surface of the shell and is most advantageously outlined, a pilot light was used just above and to one side of the center of the flash gun reflector. A number 111, 75-watt G. E. enlarger lamp proved ideal because of its small size. Through a small hole cut in the door of the dark box, the egg was kept under observation until the time of exposure.

LITERATURE CITED

BARTH, E. 1953. Calculation of egg volume based on loss of weight during incubation. Auk, **70**: 151–159.

KENDEIGH, S. 1941. Length of day and energy requirements for gonad development and egg-laying in birds. Ecology, **22**: 237–248.

KOSSACK, C. W., and H. C. HANSON. 1953. Unisexual broods in the mourning dove. Jour. Wildl. Mgt. **17**: 541.

LEVI, W. M. 1941. The pigeon. R. L. Bryan Co., Columbia, S. C. 512 pp.

PRESTON, F. W. 1953. The shapes of birds' eggs. Auk, **70**: 160–182.

RIDDLE, O. 1917. The theory of sex as stated in terms of results of studies on pigeons. Science, N. S. **46(1175)**: 19–24.

———. 1930. Studies on the physiology of reproduction in birds. XXVII. The age distribution of mortality in bird embryos and its probable significance. Amer. Jour. Physiol. **94**: 535–547.

———. 1938. The changing organism. Cooperation in research. Carnegie Inst. of Wash. **501**: 259–273.

ROMANOFF, A. L. and J. ROMANOFF. 1949. The avian egg. John Wiley and Sons, New York. 918 pp.

WORTH, C. B. 1940. Egg volumes and incubation periods. Auk, **57**: 44–60.

Accepted for publication July, 1953.

THE ROLE OF MINK AND OTTER AS MUSKRAT PREDATORS IN NORTHEASTERN NORTH CAROLINA[1]

Kenneth A. Wilson

Wildlife Resources Commission, Currituck, North Carolina

Introduction

The mink (*Mustela vison mink*) today is first in fur value in North Carolina and the otter (*Lutra canadensis lataxina*) is trapped in quantities second only to those harvested in Louisiana. Fur dealers' reports for the past five years reveal that between 12,000 and 21,000 mink and from 801 to 1,341 otters have been harvested annually by trappers in North Carolina.

Despite their fur value, mink and otter in northeastern North Carolina are believed by some trappers to be serious muskrat predators. The muskrat crop in Currituck County has dropped from nearly 40,000 in 1944 to about 20,000 in 1953. To the trapper this fact proves his point.

An investigation to determine the extent that minks and otters prey upon muskrats (*Ondatra zibethicus macrodon*) in northeastern North Carolina was initiated in the fall and winter of 1947–48 and continued each year during the legal trapping season (December 15–February 15) through the winter of 1950–51. The work was conducted as part of a study of the ecology and management of the muskrat on the Northwest River Marsh in Currituck County.

Most material for the study was obtained at the fur shed in Moyock, North Carolina, where trappers brought fur to sell in the carcass. Stomachs and intestines were preserved in 10 per cent formaldehyde. Except for a few minks and otters from nearby Dare and Camden Counties all digestive tract material came from Currituck County. Except for 11 otter scats from Pamlico County, all droppings came from the Northwest River Marsh.

The contents of 568 mink digestive tracts and 54 otter digestive tracts were examined. Of these, 335 (59%) minks and 24 (44%) otters contained food. The 233 minks and 30 otters without food were largely filled with mud, chewed leaves and twigs, toe nails, foot pads and other detritus. Sixty-one otter scats and 53 mink scats represent the dropping material.

Contents of each tract were washed in a fine-screened container, residue being placed in an electric oven to dry. Material in stomachs and entrails was studied separately, but when the same food appeared in both, it was counted only once. Tabulation of foods was made on the basis of frequency of occurrence and not by volume. Food in stomachs, whether mammal, bird or fish, was usually chewed into bits about one-half inch long, though when the diet was rabbit or prey of similar size, minks often bolted food in larger chunks. Food in otter stomachs was chewed into smaller pieces than food eaten by mink. Intestines in general contained hair, teeth, skeletal parts, fish scales, chitin and

[1] A contribution from Pittman-Robertson Wildlife Restoration Project 6-R, North Carolina Wildlife Resources Commission.

other undigested hard food remains. Otter intestines lined with about one-fourth inch of mucus for protection from fish spines and other sharp-edged foods appeared to function as repositories for undigested food, i.e., they held food accumulated over several days. No attempt was made to identify species of fish in each tract, though the residue of what appeared to be typical samples was analyzed to obtain data on the principal species consumed. Identification in general was limited by quality and kind of material (feather, tooth, hair, skeletal part, etc.) in the study sample. Study procedure for scats was similar to that employed on digestive tract foods.

ACKNOWLEDGMENTS

The writer wishes to thank Arnold L. Nelson, Director, Patuxent Research Refuge, U. S. Fish and Wildlife Service, Laurel, Maryland for the use of laboratory facilities in food identification, Francis Uhler for help in fish identification, William Stickle who identified the reptiles and many of the mammals, and Robert Stewart for aid in bird identification. Thanks are given to Lucille Stickle and Leonard Llewellyn for help with certain mammals and Robert Mitchell for assistance in identifying arthropods.

DESCRIPTION OF AREA

Currituck County is located in the northeastern corner of North Carolina, with elevations ranging from sea level to 20 feet. Of the 186,880 land acres in the county, approximately 60,000 acres are swamp and about 33,000 acres are marsh.

SWAMP HABITAT: Vegetation is largely composed of sour gums (*Nyssa aquatica-biflora-sylvatica*), red maple (*Acer rubrum*), cypress (*Taxodium distichum*), magnolia (*Magnolia virginiana*), and swamp rose (*Rosa carolina*). Sluggishly flowing creeks and ditches drain the land. Water depths in most swamps range from a few inches to a foot.

Fish, crayfish, frogs, mice, cottontail rabbits, grey squirrels and birds are common. Raccoons are abundant. The larger swamps carry deer and bear. In recently cut-over sites where there are cattails (*Typha latifolia*), muskrats are plentiful. It is believed that at least 70 per cent of all the digestive tracts came from swamps.

According to J. J. Flora, fur dealer, Moyock, North Carolina, trappers in Currituck County annually harvest about 200 minks, most of which come from swamps, and between 30 and 40 otters. About half of the latter also come from swamps. The majority of trappers seldom exceed twenty mink and one or two otter a season.

MARSH HABITAT: Most marsh acreage in Currituck County lies along the shoreline and on islands in Currituck Sound. Cover types consist principally of needle-rush (*Juncus roemerianus*), cordgrass (*Spartina cynosuroides*), sawgrass (*Cladium jamaicense*), cattails (*Typha angustifolia*, *T. latifolia*, *T. domingensis* and *T. glauca*) and Olney's threesquare (*Scirpus olneyi*). Water varies from slightly brackish to almost fresh.

Muskrat and otter are the important fur animals. Practically no mink inhabit outer banks marsh but on the mainland where swamp borders marsh, mink are common. Raccoons are numerous in all swamp-marsh cover types. Fish, frogs, crayfish, rice rats, mice, muskrats, rabbits and birds are relatively plentiful. An estimated 60 digestive tracts (10

otter and 50 mink) came from this habitat.

Normally between 30 and 40 thousand muskrats are harvested annually in Currituck County. Approximately 75 per cent of these come from marsh. In recent years, harvests from marsh habitat have dropped sharply. Muskrat trapping records for a five-year period on Tice Marsh (approximately 1,000 acres) in northern Currituck Sound reveal a drop from 958 in 1948 to 98 in 1952—a crop shrinkage of 90 per cent. The author has substantial proof that this drop in marsh production — largely county-wide — has not been caused by muskrat-eating mink and otter but by muskrat-litter-eating raccoons (Wilson, 1953).

NORTHWEST RIVER MARSH: This 1,263-acre state holding is a management study center for increased production of the muskrat. About half the property is woodland, much of it swamp and the remainder is marsh. Cover types in the approximately 650 acres of marsh are largely cattails (four species), Olney's threesquare, needlerush, sawgrass and cordgrass. Wooden diking that floods a 100-acre area is benefitting muskrats and waterfowl. Mink are common and it is estimated that at least a half dozen otters live on and travel over the area. Raccoons until recently have been abundant. All the otter and mink scat material (except 11 otter scats from Pamlico County) came from this area.

FOOD OF MINK

In February, 1951, three inches of snow on the Northwest River Marsh lasted until noon following the night it fell. Tracks of four mink, one pair and two singles, indicated that these animals were finding sufficient food in a twenty-acre swamp. Because of abundance of food in Currituck County, the mink population is believed to be heavy, and individuals do not travel for food as widely as they do in upland habitat.

Of 335 stomachs or intestines with alimental material, 181 (54%) stomachs and 305 (91%) intestines contained food or food remains. Intestines of 148 (44%) mink held only a few hairs, fish scales or other fragmentary food remains and in these instances the stomachs were nearly always empty. Stomachs and intestines often contained the same food remains. Mammal prey was found in large volumes in stomachs more often than cold-blooded animals. About half the stomachs and half the intestines contained one kind of food but between 30 and 40 per cent of the digestive tracts (stomachs and intestines) contained two food items and occasionally stomachs or intestines held four and five kinds of food. These findings differ from those of Sealander (1943) (with mink in Michigan) who said, "Usually only a single item of food was represented in the stomach and intestines of an animal." Stomachs filled to capacity ordinarily contained only one food item.

Passage rates of certain foods through digestive tracts were different. Stomachs filled with mammal and bird material apparently pass hair and feathers into the intestines first, retaining fleshy pieces. Sloughed fish scales went into intestines first, skeletal parts last. More crayfish and other arthropod remains were found in intestines than in stomachs. Colon parts nearly always contained the bulk of intestinal food remains. These findings tend to confirm those of Dearborn (1932) and Sealander (*op. cit.*).

Scats were largely composed of hair, bones, feathers, chitin and the small cycloid scales of minnow-size fishes.

Results of the dropping and digestive tract studies disclose wide differences in prey items. In the digestive tract study, principal diet was fish with mammals of secondary importance. Diet largely represented foods from swamp habitat. On the other hand, droppings from the Northwest River Marsh show mammals, especially rice rats and deer mice as the popular foods, while only a few samples contained fish. Muskrat, both in tracts and droppings, represented a minor food item.

Hamilton (1940) in New York and Sealander and Dearborn in Michigan found muskrat to be an important food of mink. Sealander's work revealed that male mink consumed more muskrats than the smaller female and suggested

TABLE 1.—FALL AND WINTER FOODS OF MINK 1947–48 — 1950–51
Based on contents in 335 digestive tracts and 53 scats

Food	Frequency of Occurrence			
	Digestive Tract	Per Cent	Scat	Per Cent
FISH	204	61	7	13
Killifish (Cyprinodontidae)	..	..	..	..
Mosquito fish (*Gambusia*)	..	..	..	..
Yellow perch (*Perca flavescens*)	..	..	..	..
Sunfish (Centrarchidae)	..	..	..	..
Catfish (Ameiuridae)	..	..	..	..
Eel (*Anguilla bostoniensis*)	..	..	..	..
Pickerel (*Esox*)	..	..	..	..
MAMMALS	115	34	38	71
Deer mouse (*Peromyscus sp.*)	28	..	13	..
Meadow mouse (*Microtus sp.*)	21	..	2	..
House mouse (*Mus musculus*)	1	..	..	..
Rice rat (*Oryzomys p. palustris*)	5	..	22	..
Norway rat (*Rattus norvegicus*)	3	..	..	..
Muskrat (*Ondatra z. macrodon*)	16	..	1	..
Rabbit (*Sylvilagus*)	11	..	..	..
Gray Squirrel (*Sciurus carolinensis*)	7	..	..	..
Opossum (*Didelphis v. virginiana*)	1	..	..	..
Short-tailed shrew (*Blarina telmalestes*)	10	..	..	..
Star-nosed mole (*Condylura c. cristata*)	1	..	..	..
Unidentified mammals	11	..	..	..
BIRDS	59	18	16	30
King rail (*Rallus e. elegans*)	8	..	6	..
Virginia rail (*Rallus limicola limicola*)	2	..	..	..
Black duck (*Anas rubripes*)	1	..	1	..
Ruddy duck (*Oxyura jamaicensis*)	1	..	..	..
Florida gallinule (*Gallinula chloropus cachinnans*)	1	..	..	..
Flicker (*Colaptes auratus*)	2	..	..	..
Whip-poor-will (*Caprimulgus vocifera*)	1	..	..	..
Unidentified birds	43	..	9	..

TABLE 1. – Continued

ARTHROPODS	102	30	9	17
Crayfish (*Cambarus*)	44	..	3	..
Insect	31	..	4	..
Beetle (Coleoptera)	..	..	..	..
Water beetle (Dytiscidae)	..	..	..	..
Katydid (Tettigoniidae)	..	..	..	..
Spider (Araneae)	13	..	1	..
Wolf spider (Lycosidae)	..	..	..	..
Decapod	12	..	..	..
Shrimp (Decapoda)	2	..	1	..
AMPHIBIANS				
Frogs (*Rana* and *Hyla*)	42	13	5	9
REPTILES	16	..	..	..
Water snake (*Natrix sp.*)	11	..	..	..
Garter snake (*Thamnophis sp.*)	2	..	..	..
Rat snake (*Elaphe sp.*)	2	..	..	..
Unknown snake	1	..	..	..
Turtle (Testudinata)	..	..	1	..
MOLLUSK				
Snail (*Planorbis*)	..	..	1	..

"the size of a mink may determine the size of its prey." Coastal mink are known for their small size, while muskrats are relatively large. Thirty-three adult male and thirteen adult female mink averaged 1 lb. 8 oz. and 1 lb. 1 oz., respectively, while the average weight of 488 adult muskrats approached 3 lbs. At least three of the seventeen muskrats consumed were kit-size (a pound or less) and it is possible, with the numerous sources of easily obtained foods, that mink would prefer these to strenuous conflict with the muskrat.

The study failed to disclose the amount of food in terms of volume and grams that wild mink consume during a 24-hour period. About 15 of every 100 stomachs contained an "abundance" (from 30 to 120 grams) of food but in many instances considerable digestion had started.

DIGESTIVE TRACT FOODS: Fish: Of the 335 tracts, fish were found in 204 (61%). Killifish and mosquito fish, both small non-game varieties, made up the bulk of this food. Possibly 10 per cent of the samples contained remains of the following fish: sunfish, catfish, eel, yellow perch and pickerel. Large quantities of small fish species inhabit shallow coastal waters. Consistent consumption of this food suggests that it is eaten in quantity, at least in the fall-winter months and possibly the year round.

Mammals: Approximately one-third (34%) of the study material contained mammals. Deer mice occurred in 28 tracts, (Table 1). During the severe winter of 1948–49, in which more than twenty inches of snow fell, it is noteworthy that only 5 of 103 mink had eaten mice. Intermittent cold weather with snow probably made hunting them more difficult or possibly populations were down. During the same winter, however, fish (74 times) and crayfish (24 times) were eaten more frequently

than at any other time during the study. Scarcity of rice rats (only 5 recorded), is puzzling since scats from the Northwest River Marsh and live-trapping there, indicate heavy populations of this species. Of 538 items in the study identified as food, mammal prey larger than small rodent sizes appeared only 35 times (7%) (Table 1). Except for opossum, all these animals are common in swamp and marsh habitat. Again it would appear that when food is abundant, mink choose the easier-to-obtain prey species. The remainder of mammalian food consisted of shrews, Norway rats, and one mole.

Arthropods: Crayfish comprised the bulk of this food which was represented in 44 (13%) tracts. Intestines usually contained the largest volume, and 25 per cent greater frequency than stomachs, presumably because of accumulations of indigestible parts. In Michigan, Dearborn (*op. cit.*), found crayfish a minor food of mink in the winter, but an important summer food. Study of mink foods during the summer when large crayfish populations are active would show greater consumption of this crustacean. Other arthropods (all minor foods) represented were decapods, shrimp, beetles, katydids and spiders.

Birds: Birds are not important in the diet of mink. Although 59 (18%) animals contained bird, only a few appeared in volume. Six species of birds were identified, of which king rails (8), by volume and frequency, formed the largest percentage. Of the small birds (mostly passerines) that could not be identified, many probably were warblers and sparrows. Only large species appeared in volume, mostly in the stomach. Most bird remains (60%) were located in the intestines. Often the evidence was only part of a foot, bill and bone fragments, or a feather.

Amphibians: By volume and frequency (11%) frogs comprised a small part of the diet. Except during the winter of 1950–51 when they were found in 28 of 103 mink, few were consumed. Hibernation would reduce the predation rate on this animal though occasional winter warm spells bring them (mostly Hylidae) out. Why a relatively large number of frogs were taken only in the 1950–51 winter, which was colder than average, cannot be explained. As with crayfish and birds, most (70%) frog remains—largely bones—were found in the intestines. The general absence of skin precluded identification beyond *Hyla* and *Rana*.

Reptiles: Sixteen (5%) tracts contained snakes, mostly watersnakes. During the severe winter of 1948–49, snakes were eaten by 12 of 103 mink but in two mild winters in which the weather was warm enough for muskrats to mate in January, no reptiles were eaten. Why it happened this way cannot be explained. Despite numerous cottonmouth moccasins (*Agkistrodon piscivorus*) in the county, none was found and it is doubtful that mink eat them at any time except possibly as carrion. Non-poisonous snakes, however, are doubtlessly consumed more frequently during warmer seasons of the year.

SCATS: Prey items in the droppings largely represent fall foods. Analyses of the 53 scats disclosed mammals (72%) to be the principal foods. Of these, rice rats appeared in 22 (42%) droppings and deer mice in 13 (25%). Though common in parts of the Northwest River Marsh, only one of the 53 droppings

contained muskrat—bones and hair of a young animal. Of 16 (30%) droppings that contained birds, king rail appeared in six, black duck in one. King rails are relatively plentiful in the area and black ducks are common. Each year about 100 spend the winter on the 1,300 acre refuge. Most of the unidentified birds were small passerines. Fish, plentiful in the digestive tract material, were found in only 7 (13%) scats. Minnows and other small forage fish made up the bulk of this food. Other foods found in small quantities were frogs, insects (katydid and beetles), crayfish, meadow mice, turtle, snail, shrimp and spider.

FOOD OF OTTERS

In 1947, when the author came to North Carolina, trappers complained of destruction of muskrat populations and other deeds committed by otter. The principal complaints were that otters tear open houses and devour muskrats in their beds, consume muskrats in traps and create panic among muskrats, causing them to leave their homes. Scats at two large otter toilets on the outer banks were shown to me by a bitter trapper in 1949, but examination revealed that what looked like muskrat hair was actually shredded feather remains of waterfowl. At the time (January), the waterfowl season had just closed and marshes contained the remains of dead coots (*Fulica americana*), other dead waterfowl, and some crippled ducks unable to fly. Of many hundred droppings the author has observed at toilets or pulverized for quick examination in the hand, almost everything, excepting occasional feathers, has appeared to be either fish or crustaceans. Trappers (many are apprehensive of another closed season on otters) also observe similar droppings but despite the evidence, some still complain about muskrat-eating otters.

The digestive tracts of 30 (56%) otters contained small quantities of masticated grass and woody vegetation, mud and sand apparently ingested while the animals were in the traps.

In 24 (44%) digestive tracts, most food was in the intestines. These data, coupled with the fact that a majority of the 54 tracts were empty, indicate most otters were found alive in traps.

The author does not know the rates of food passage through the alimentary canal. It was noted, however, that the intestinal content of fleshy food (fish and bird) was smaller by the proportion of food ingested than the intestinal content from consumption of hard foods (crayfish and crabs). In other words, the exoskeletal remains of a couple of one-ounce crayfish would approach or exceed the residue from a one-pound bass. Awareness of this fact is important in evaluating foods consumed by otters and mink.

Droppings were composed of indigestible food remains, largely fish scales, pectoral fins, skeletal parts and chitin.

DIGESTIVE TRACTS AND SCATS: Fish occurred in 91 per cent of the tracts and scats, and crustaceans—crayfish, blue crab, decapod, shrimp, in 39 per cent (Table 2). Of all the foods consumed, the volume of fish was estimated at 80 per cent and crustaceans 15 per cent. Traces of water beetle, (possibly eaten by fish) were located in five droppings. Birds (one king rail and two unidentified) were found in two scats and one tract. Scats (3) and tracts (2) contained the bones of five frogs, *Rana* sp. One stomach contained clam (Pelecypoda)

TABLE 2.—FREQUENCY OF OCCURRENCE OF FALL AND WINTER FOODS OF OTTERS, BASED ON CONTENTS OF 24 DIGESTIVE TRACTS AND 61 SCATS

Food item	Frequency of occurrence Per cent
Fish	91
Crustaceans (crayfish and blue crab)	39
Insects (water beetles)	6
Birds	3
Muskrat	1
Clam	1
Bait	1

TABLE 3.—FISH EATEN BY OTTERS FROM CURRITUCK COUNTY, NORTH CAROLINA Based on contents in 10 digestive tracts and 20 scats

FOOD	Times Occurring	Per Cent
Forage Fishes	26	57
Carp	5	11
Suckers	5	11
Killifish	4	9
Minnows	3	7
Eels	3	7
Shiners	2	4
Mosquito fish	2	4
Bowfin	2	4
Game and Panfishes	20	43
Sunfish	7	15
Catfish	5	11
White perch	3	7
Pickerel	3	7
Yellow perch	1	1.5
Large-mouth bass	1	1.5

and another stomach, liver (bait). Intestines of one otter held the hair of an adult muskrat.

Since the objective of the study was to determine the role of otters as muskrat predators, no effort was made to identify all the fish species. However, an attempt was made to obtain approximate data on the frequency of their consumption by family (genera and species where possible). To do this the food in 10 stomachs and 20 droppings was analyzed (Table 3).

Scales and skeletal remains of eleven families were represented in the material, six families of forage fish (57%) and five families of game and pan fishes (43%).

The principal food in eleven scats from Pamlico Sound was flounder (Pleuronectidae). Two unidentified specimens of marine fish were also recorded.

SUMMARY

A 4-year (fall and winter) collection, 1947–48 to 1950–51, of mink and otter digestive tracts and a 2-year (fall of 1950 and 1951) collection of mink and otter scats included material most of which was from Currituck County, North Carolina.

Analysis of 568 digestive tracts, 335 of which contained food, and 53 scats disclosed that muskrat is a minor fall-winter food of mink.

Digestive tract food by frequency (61%) and volume was largely fish. Mammals (34%) and arthropods (30%), next in importance, were largely mice and crayfish, respectively. Of the birds (18%), most were small passerines. Among seven species identified, king rail was prominent. Other foods were frog and snake. Sixteen of the 335 tracts contained muskrat.

Mammal prey in mink scats from the Northwest River Marsh constituted more than 70 per cent of the food by frequency. The remainder consisted of birds, frogs, insects, crayfish, spiders, turtle, snail and shrimp.

Rice rats and deer mice were the most important prey items. Small birds ranked next, followed by fish and frogs. One scat contained remains of a young muskrat.

Otter foods, both in tracts and droppings, were largely fish. Of 24 tracts and 61 droppings, largely representing winter diet, fish by frequency was in more than 90 per cent. Other foods were crayfish, blue crab, water beetles, bird (mostly king rail), shrimp, decapod, clam, bait, and one muskrat.

Forage fish and game fish constituted 54 per cent and 46 per cent by frequency, respectively. Of the former, carp and suckers were favorites, while among the latter, the choice was sunfish and catfish.

Food contents of 11 droppings collected in June, 1951 from Pamlico County were principally fish (flounder) and crustaceans (blue crab, crayfish) but no muskrat.

LITERATURE CITED

DEARBORN, N. 1932. Foods of some predatory furbearing animals of Michigan. School of Forestry and Conservation, Univ. of Mich. Bull. No. 1. 52 pp.

HAMILTON, W. J. JR. 1940. Summer foods of minks and raccoons on the Montezuma marsh, New York. Jour. Wildl. Mgt., **4**: 80–84.

SEALANDER, J. A. 1943. Winter food habits of mink in southern Michigan. Jour. Wildl. Mgt., **7**: 411–417.

WILSON, K. A. 1953. Raccoon predation on muskrats near Currituck, N. C. Jour. Wildl. Mgt., **17**: 113–119.

Accepted for publication June 20, 1953.

DISPERSAL, GROWTH, AND INFLUENCE OF SMALLMOUTH BASS STOCKED IN A WARM-WATER STREAM [1]

R. Weldon Larimore

Illinois Natural History Survey, Urbana, Illinois

Many warm-water streams in North America have been stocked with bass, but in only a few instances have the effects of stocking been carefully and objectively measured.

In 1951 an experiment was begun to determine the effects of releasing smallmouth bass, *Micropterus dolomieu* Lacépède, in Jordan Creek, a small stream in east-central Illinois that already supported a native smallmouth population. A census of the total fish population and a survey of stream habitat in July-September, 1950 (Larimore, Pickering, & Durham 1952), preceded this experiment by one year and served as a basis for judging results of stocking.

Study of the fishes of Jordan Creek has been continuous since the census of 1950. Observations have covered reproduction, movements, food supplies, species relationships, and seasonal fluctuations of fish populations. Tempera-

[1] This study was sponsored jointly by the Illinois Natural History Survey and the Illinois Department of Conservation.

tures and water levels were recorded. A major objective of this intensive investigation was to determine factors which control population density and growth of smallmouth bass in small streams. It was with this in mind that the stocking experiment was begun. By adding smallmouths to a known indigenous population of these fish and by following survival, growth, and dispersal of both native and introduced fish, the factors controlling population density might become evident.

Jordan Creek is a small tributary of the Salt Fork of the Vermilion River, Vermilion County, Illinois. It arises in a flat to rolling area, flows through open pasture and into rough woodland. The four-mile section that has been intensively studied, which includes most of the water suitable for bass and sunfish, is about equally divided between wooded and open areas. It was in the region of transition between these habitats and approximately midway in the study area (1.9 miles from the creek mouth) that smallmouths were stocked.

STUDY METHODS

Five groups of smallmouth bass were released in Jordan Creek (Table 1). Four of these groups were composed of smallmouths taken from a three-acre artificial impoundment known as Sparks Pond. These fish were all of the 1950 year-class and, with the possible exception of those stocked in April, 1952, which were beginning their third year of life, could be considered yearling bass at the time of their release in Jordan Creek.

The fifth group consisted of smallmouths from Stony Creek, a stream slightly larger than Jordan Creek but a tributary of the same drainage system. Stony Creek enters the Salt Fork River one and one-half miles above the mouth of Jordan Creek. The fish in this group were from the 1949 and 1950 year-classes and were somewhat larger in average size then those from Sparks Pond.

The fish of each group were transported in aerated tanks to the place of stocking. Before being released, they were measured, marked by fin removal, and carefully conditioned to the stream temperature. A different fin was removed for each group. Bass from Stony Creek were given numbered opercular tags in addition to being fin-clipped. Only those fish which appeared to be in good physical condition were used.

An electric seine, operating from a 115-volt, AC generator, has been em-

TABLE 1.—SMALLMOUTH BASS TAKEN FROM SPARKS POND AND STONY CREEK AND RELEASED IN JORDAN CREEK; JULY 1951 THROUGH APRIL 1952

Group	Date of Release	Number Released	Average Total Length (inches)	Standard Deviation
Sparks Pond				
Group 1	July 25, 1951	82	6.3	0.72
Group 2	Aug. 9, 1951	55	6.4	0.61
Group 3	Oct. 10, 1951	50	6.5	0.47
Group 4	Apr. 26, 1952	40	7.0	0.57
Stony Creek				
Group 5	Apr. 28, 1952	21	8.6	1.42

ployed in the population studies of Jordan Creek. Persistent use of the shocker in following seasonal and annual changes in the population throughout the study area has made it possible to follow the growth and distribution of these stocked fish. When first recaptured the pond-reared fish were given numbered opercular tags, so that subsequent movements of individual fish could be followed.

MOVEMENTS OF STOCKED FISH

The small pool in which the fish were released included a pocket of still water and the cover of a large boulder. It afforded a place for them to become adjusted to the new situation without being swept downstream by the main force of the stream nor immediately required to move against the current. The pool was too small, however, to support permanently more than one or two bass, so that the fish were gradually compelled to move from their place of release.

Most of the fish from each group moved upstream from where they were introduced. This was first discovered when a census was made of the section of stream extending 0.4 mile below and 0.4 mile above the place of stocking. The census of this 0.8-mile section was conducted during the third week in August, 1951; fish of Group 1 had been in Jordan Creek approximately three weeks, those of Group 2, only one week. Of 29 bass retaken from the first group, 24 (83 per cent) had moved upstream. From the second group, 33 bass were collected of which 32 (97 per cent) had moved upstream. This section of stream was again censused during May, 1952, after all groups had been stocked (Table 1). At this time, 75 per cent of the stocked fish retaken were above the place of release, with approximately the same proportion of each group having moved upstream. The following August, 68 per cent of the stocked fish taken in this section were above the place of release.

The gradual decline in percentage of stocked fish taken in the upper part of the 0.8-mile section was not due to a shift of fish downstream, for there was no increase in the number of stocked bass taken in the lower part of this section during the later collections. The decline was caused by the continued dispersal of stocked fish into parts of the stream above the 0.8-mile section that contained the point of release.

The uneven distribution of stocked fish throughout the stream was revealed by a census of the entire four-mile study area made during July-September, 1952. As had been done in previous censuses, the fish were tabulated by half-mile divisions of the stream to allow comparison of the abundance of fish found in equal lengths of stream. The divisions were numbered from the mouth of the creek upstream, and it was in the upper one-third of Division 4 that the smallmouths were stocked. Seventy-five of the 227 pond-reared smallmouths were retaken and of these, 57 (76 per cent) were in Division 4 in which they were released or in the next division upstream (Figure 1). Fourteen of 75 collected had moved downstream, but only four were more than 0.4 mile below the stocking place. Five of the 21 Stony Creek bass were retaken but these showed no special pattern of distribution, being scattered singly up and down the stream.

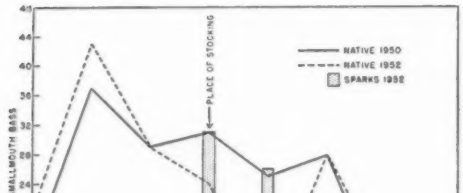

FIG. 1. Distribution of native and Sparks Pond smallmouths taken in the eight divisions of Jordan Creek during the censuses of July-September 1950 and 1952.

Recaptures of tagged bass have indicated how soon the stocked fish become established in a particular area and cease moving from one pool to another. Eighty-two pond-reared bass have been retaken one or more times after receiving tags. Of these recaptures, 52 (63 per cent) had not moved since being tagged. The remaining 30 had continued to move, 14 having moved upstream and 16 downstream. About one-half of these moves occurred during the late fall and early spring—that is, soon after stocking. Twenty-three of the 30 recorded moves were made by the following August, 1952. Three of the seven moves recorded for the fall months were by fish which had not been taken since May, so that these moves might also have occurred during the summer. The percentage of tagged fish which had moved declined steadily from the time of stocking, indicating that the majority of the stocked bass were claiming home pools, at least temporarily. Smallmouths from Stony Creek did not show this tendency to establish home areas; recaptured bass were never in the same pools as where previously taken. Investigations in Stony Creek disclosed that some of the fish in this group had returned to their home stream, having gone down Jordan Creek, up the Salt Fork River, and up Stony Creek to the original pool, a trip of 5.25 miles.

The four groups of pond-reared bass (Table 1) showed some differences in movements. Those that were released in the summer of 1951 and spring of 1952 (Groups 1 and 4) tended to scatter out more than those released later in the summer and fall of 1951 (Groups 2 and 3). Group 4 dispersed more than the three groups released earlier, possibly because the nearby pools were already crowded with recently stocked bass. The longer the fish were in the creek the greater was their tendency to remain in one place.

GROWTH OF STOCKED FISH

Measurement of growth has been used to evaluate the success of smallmouths stocked in Jordan Creek. A considerable number of the pond-reared bass were recaptured one or more times after being released, so that a dependable record of their growth is available. On the other hand, the bass from Stony Creek varied so much in total length (standard deviation = 1.42) when transferred to Jordan Creek and so few of them were later retaken, that it was possible to show only that their growth was comparable to that of the indigenous smallmouths in this stream.

There was a definite mark formed on the scales of the stocked fish, corresponding to the time of their transfer to Jordan Creek and indicating a stoppage in growth. That the cessation of growth

was brief, however, was indicated by the measurements of 29 bass of Group 1, recaptured after having been in Jordan Creek for only three weeks. When stocked these fish averaged 6.3 inches total length, when recaptured 7.3 inches, an apparent increase of 1.0 inch. However, a statistical examination of the recaptured fish indicated that they were not representative of the original group of 82 fish ($X^2 = 15.91$, df = 28). Selective sampling may have been caused by a weir at the upper end of the stream section from which this collection was taken. Even though the largest of the pond-reared bass could get through this weir, the movements of the larger individuals may have been retarded more than those of the smaller ones. Nevertheless, it can be shown that a significant amount of growth had occurred. The largest 29 fish in the original group averaged 7.0 inches in length and so, compared to the average of 7.3 inches for the 29 recaptures, there was a length increment of at least 0.3 inch during the three-week period.

After only one week in the stream, 33 fish recovered from Group 2 averaged 6.6 inches in length, 0.2 inch more than the original average of 6.4 inches for the entire group. Although there was no evidence that this was not a random sample of the original group ($X^2 = 33.21$, df = 32), the difference of 0.2 inch is not significant ($t = 1.48$).

All the later collections of stocked fish appeared to be representative of their original groups, including the ones taken during the fall and winter months before the weir was removed in March, 1952. The weir may not have influenced the early movements of any fish but those of Group 1, for relatively few of the other stocked bass dispersed as far upstream as the weir until after it had been removed.

That the Group 3 bass stocked in October, 1951 did not grow until the following spring was shown by scale examinations and by the average length of a series of these fish taken during February which was slightly smaller (0.1 inch which is statistically insignificant) than that of the entire group the previous October. Comparison of measurements of fish from Group 1 in October and February also showed that the season's growth was completed by early October.

Collections of fish from Groups 1 and 2 averaged exactly the same during the third week in May as they did in February, so it was believed that the fish did not start growing until after mid-May. This assumption was further confirmed by scale examinations. Neither Group 3 nor Group 4 showed growth by the middle of May that was statistically significant.

Collections indicated only slight differences between the growth rates of the four groups during the succeeding season of 1952 (Figure 2). From May through August the groups showed similar length increases. Only after August were differences in growth rate apparent. Growth rate of Groups 1 and 2 apparently decreased slightly during September and October, whereas the two other groups continued approximately the rate of growth maintained during the summer. As a result of this difference, the average computed lengths of Groups 3 and 4 were greater at the end of September, 1952, than that of Group 2 and the fish stocked last (Group 4) were approximately the same average length as those

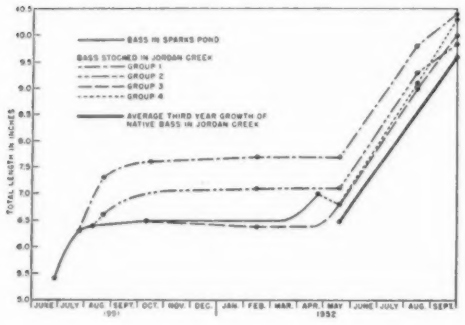
BASS IN SPARKS POND
BASS STOCKED IN JORDAN CREEK
GROUP 1
GROUP 2
GROUP 3
GROUP 4
AVERAGE THIRD YEAR GROWTH OF NATIVE BASS IN JORDAN CREEK
TOTAL LENGTH IN INCHES
JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT.
1951
1952

FIG. 2. Growth of smallmouth bass of the 1950 brood in Sparks Pond and of four groups taken from this brood and released in Jordan Creek. Given for comparison is the average calculated growth during the third growing season of four year-classes (1946–1949) of smallmouths native to Jordan Creek.

first released (Group 1).

Growth of these stocked fish during their first season in Jordan Creek was as good as that of the indigenous smallmouths. The average growth during the third year of life was determined for four year-classes (1946–1949) of native bass in Jordan Creek and compared with the growth of stocked fish (Figure 2).

There was no indication that competition of the stocked bass affected the growth of the native smallmouths. The actual lengths of a number of native smallmouths measured during the early fall—probably near the end of the growing season—indicated that the 1952 growth was very similar to that of previous years. If there was any decrease in growth rate of native bass, it was too slight to be evident in the data now available.

INFLUENCE OF STOCKED FISH ON THE TOTAL BASS POPULATION

Usually, the most important consideration in assaying the value of stocking is whether the number of desirable fish in a limited water area has been increased. In the Jordan Creek studies, interest was further focused on the native population, as to whether any change in their numbers or distribution resulted from the introduced fish.

These problems were examined by comparing the smallmouth populations of the entire study area taken during the 1950 and 1952 censuses (Table 2).

TABLE 2.—NUMBERS OF NATIVE AND STOCKED SMALLMOUTH BASS (EXCLUSIVE OF FINGERLINGS) TAKEN DURING THE 1950 AND 1952 CENSUSES OF THE 4-MILE STUDY AREA OF JORDAN CREEK

Size	1950	1952		
	Native	Native	Stocked	Total
Sub-legal size*....	116	93	44	137
Legal size*	68	73	36	109
Total.....	184	166	80	246

* Legal total length is 10 inches in Illinois.

Fingerling smallmouths (young-of-the-year) are not considered in the comparison of these censuses because of their unstable position in the total population. Both censuses were begun during the last week in July and completed by the second week in September. Within the two-year period separating these censuses, the new smallmouths were stocked; thus the censuses gave a population inventory one year previous to and one year after the introduction of new fish.

Before comparing the numbers of bass taken in the 1950 and 1952 censuses, we should consider the efficiency of our collecting. Field tests conducted under average conditions in Jordan Creek have shown that with the electric seine we

were able to recover between 65 and 80 per cent of the bass present in a pool. Efficiency varied according to the type of habitat being worked. The following figures have not been adjusted to the collecting efficiency, so one should keep in mind that the number of fish present in the creek was proportionately greater than the data show.

The influence of stocking would depend to some extent on the relationship between number of fish stocked and the number of fish in the native population. The 248 smallmouths stocked was 1.3 times the total number taken in the 1950 census (exclusive of fingerlings). And since the fish stocked were below the legal length of 10 inches, it is relevant that the number stocked was 2.1 times the number of bass of sub-legal size taken in the first census.

The indigenous population taken in the 1952 census was 10 per cent lower in number than that of 1950 (Table 2). There was a slight increase (seven per cent) in legal-sized bass, so that the total decrease was among the smaller fish. The lower number of small bass was mainly due to the loss of the 1951 brood during early June floods that year. Because there was no great change in the numbers of legal-sized bass and because the reduction of smaller fish can be accounted for, the population of native bass reveals no decline in numbers which might be attributed to the introduction of additional bass. The total smallmouth population in 1952, including stocked fish, was actually 34 per cent greater than in 1950. This included a 60 per cent increase in legal-sized smallmouths. The stocked bass comprised one-third of the total number of smallmouths, with these same proportions among both the bass of legal length and those of smaller size.

Eighty stocked bass were collected in the 1952 census. This represents a 32 per cent return of the total number originally released. The percentages of recaptures varied considerably for each group. Group 1 showed the lowest rate of recaptures (23 per cent); whereas Group 4, the last group of pond-reared fish to be stocked, produced the highest returns (45 per cent). Group 2, released only three weeks after the first group, showed returns almost as high (44 per cent) as Group 4. Group 3, released about two months later than Group 2, showed returns (28 per cent) only slightly better than the first group released. The Stony Creek bass were released last but were retaken in about the same proportion (24 per cent) as the first group stocked.

These percentages of recaptures did not decline in relation to the time each group had been in Jordan Creek. The members of Group 1 attained legal length sooner than the others and were then removed if caught by anglers. There is evidence, part of which has already been mentioned, that the Stony Creek bass left the stream more readily than those from Sparks Pond.

Even though there was no evidence that the introduced fish had caused a decline in the total number of smallmouths in the native population, the number of native smallmouths had dropped off considerably in several pools containing concentrations of stocked fish. The decrease in numbers between the 1950 and 1952 censuses amounted to 22 and 68 per cent in Divisions 4 and 5 respectively, the divisions in which 76 per cent of the pond-reared fish were

collected (Figure 1). All the decline in Division 4 took place above the pool in which the fish were stocked; that is, only in that part of the division that contained concentrations of stocked fish. The greatest decline occurred in Division 5 in which there was a 68 per cent decrease in the numbers of native smallmouths. A drastic change in habitat at the upper limit of the study area caused the decline in smallmouths exhibited by Division 8.

The reduction in number of native smallmouths in the area crowded by stocked fish (upper one-third of Division 4 and all of Division 5) suggests that the native fish either left the crowded area or were removed and were not replaced by other native fish.

Evidence that they moved to other parts of the stream was sought in the movements of tagged native smallmouths. Of 20 native bass originally tagged in this crowded area and recaptured between August, 1951, and May, 1952, only two had left this section of stream. At the same time, three native bass entered the area after having been tagged in other parts of the creek. This amount of movement into and out of the area was expected, being similar to that found in the parts of Jordan Creek not influenced by stocking. Thus, these early recaptures indicated no definite displacement of native bass during the first winter and spring following stocking.

Recaptures made during the late summer of 1952 gave a somewhat different impression of such movements. Ten native bass which had been in the area (upper one-third of Division 4 and Division 5) between August, 1951, and May, 1952, were retaken the following fall. Only four of the ten had remained in the area. Of the six leaving, two moved upstream, four downstream. The increase in number of native bass leaving the area may have been a natural occurrence of the season, but it seems more likely to have been an effect of crowding by the introduced fish. During the growing season the increased population pressure would have been felt, causing some of the native fish to relinquish their original places in the stream.

The other possible cause for a decline of native fish in this crowded section might be the lack of natural replacement of an increased number of smallmouths removed by anglers. As has been previously observed (Larimore 1952), there are certain bass in any pool or part of Jordan Creek that are only temporary residents. These fish shift from one place to another and probably replace the losses of more sedentary individuals, thus maintaining a population balance throughout the stream. Even though there was a greater number of smallmouths taken by anglers in this crowded area than in similar parts of Jordan Creek, there would be no replacement by native fish as long as the population density remained higher than in the rest of the stream.

DISCUSSION

Stocking in Jordan Creek was used as an experimental technique in the investigation of factors controlling the population density and growth of smallmouth bass in this stream; the preliminary results neither condemn nor indorse the stocking of streams.

It was believed that reproduction, food supply, and suitable pools for bass might be factors limiting population density and growth of smallmouths. Re-

production of bass is frequently unsuccessful in small streams because of high waters at nesting time. Both the 1951 and 1952 broods of smallmouths in Jordan Creek were virtually destroyed by early-summer floods. If such losses reduce the total stream population, then the addition of fish by stocking should increase the population. On the other hand, if reproduction was not a limiting factor, stocking might produce no lasting increase in the number of bass present.

In a population whose density is great enough that the abundance or availability of bass foods are limiting conditions, the addition of fish to the existing population would cause greater competition for food and consequently a general reduction in growth. Such an effect was not observed in Jordan Creek in the year after stocking. Both the native and introduced smallmouths exhibited growth rates similar to that of the bass during previous years in this stream.

The number of pools suitable for bass may determine the population density that a stream can support. If it does, the size of the population would be relatively constant and would vary only as the habitat changed. There is no doubt but that a small stream has a rather limited number of pools which appear suitable for bass, but the preliminary results of stocking smallmouths in Jordan Creek indicate that many pools did not contain a maximum number of bass and that other less desirable areas could support bass crowded from the choice places.

Whatever the factors might be that control population and growth of smallmouth bass, they might be expected to be different in different streams or even to change from year to year in the same stream. No harmful effects of stocking were observed in Jordan Creek during the first year of this experiment and it is recognized that the desirable result of increasing the total population may be only temporary. If Jordan Creek cannot support this greater population, it is anticipated that either the number of smallmouths will decline to approximately that found in the original census or the growth rate of the bass in the stream will fall below that observed in the native fish previous to the stocking.

ACKNOWLEDGMENTS

Messrs. Leonard Durham, Quentin H. Pickering and James F. Opsahl, employed by the Illinois Department of Conservation, and Messrs. David W. Menzel and W. Leslie Burger, employed by the Illinois Natural History Survey, assisted in censusing the fishes of Jordan Creek, in collecting the smallmouth bass for stocking, and in marking the fish. Mr. Durham also helped with growth determinations.

Methods of statistical treatment of growth data were suggested by Dr. H. W. Norton, Professor of Agricultural Statistics, University of Illinois. Mr. James S. Ayars, Editor of the Illinois Natural History Survey, read the manuscript and suggested improvements.

Dr. George W. Bennett, Head of the Section of Aquatic Biology, and Mr. Sam A. Parr, Superintendent of Fisheries, Department of Conservation, arranged for support of the field investigation and offered constructive criticism.

SUMMARY

1. Smallmouth bass were added to a known indigenous population of this

species in Jordan Creek. The survival, growth, and dispersal of both the native and stocked fish were followed to determine factors controlling the population density of bass in small streams.

2. Five groups of smallmouths, mostly yearling fish, were released in Jordan Creek between July, 1951, and April, 1952. Four of these groups were composed of pond-reared bass; the other group consisted of fish from nearby Stony Creek. A total of 248 fish were released, which was 1.3 times the total number of smallmouths taken in the 1950 census of Jordan Creek.

3. The four-mile study area of Jordan Creek was censused one year before (1950) and one year after (1952) the new bass were stocked. These censuses served as a basis for judging the preliminary results of stocking.

4. Most of the fish in each group moved upstream from where they were released. The July-September census of 1952 showed that 75 per cent of the pond-reared bass were still in the one-half-mile division in which released or in the next one-half-mile division upstream. The smallmouths from Stony Creek revealed no special pattern of distribution but were scattered singly up and down the stream.

5. The longer the pond-reared fish were in the stream the greater was their tendency to remain in one place. By the fall of 1952, most of these bass were claiming home pools, at least temporarily.

6. Growth of the stocked bass during their first season in Jordan Creek was as good as that of the indigenous smallmouths. There was no indication in this season that competition of the stocked bass affected the growth of the native smallmouths. Only slight differences were evident between the growth rates of the four groups of pond-reared fish.

7. Thirty-four per cent more smallmouths (excluding fingerlings) were taken in the 1952 census of the entire study area than in the 1950 census. The number of legal-sized bass was 60 per cent greater. The increase in numbers was approximately equivalent to the number of stocked fish retaken. There was no evidence in the year after stocking that the introduced bass caused a decline in the total number of native smallmouths.

8. The number of native smallmouths dropped off considerably in several pools containing concentrations of stocked fish. The decline may have been caused by the moving of native smallmouths to other parts of the stream or by the lack of replacement by native fish for those removed by anglers.

LITERATURE CITED

LARIMORE, R. W. 1952. Home pools and homing behavior of smallmouth black bass in Jordan Creek. Ill. Nat. Hist. Surv. Biol. Notes 28. 12 pp.

———, Q. H. PICKERING, and L. DURHAM. 1952. An inventory of the fishes of Jordan Creek, Vermilion County, Illinois. Ill. Nat. Hist. Surv. Biol. Notes 29. 26 pp.

Accepted for publication April 4, 1953.

ECOLOGY OF MARSH RACCOONS[1]

Robert S. Dorney

Wisconsin Conservation Department, Ladysmith, Wisconsin

This study was undertaken in 1949 and 1950 in an effort to understand the ecological relationship between raccoons (*Procyon lotor*) living in marsh habitat and muskrat (*Ondatra zibethica*) and waterfowl populations. Because marsh raccoons may occur in high densities, a knowledge of their feeding habits is necessary to predict possible injurious effects on muskrat and waterfowl populations. This paper will consider the populations, food habits and denning habits of raccoons living on a marsh managed for muskrats and waterfowl.

Description of Area

Horicon Marsh, located in Dodge County near Horicon, Wisconsin, is a muskrat and waterfowl area managed jointly by the U. S. Fish and Wildlife Service and the Wisconsin Conservation Department. This study was conducted in 1949 and 1950 primarily on the 9,000 acres of aquatic habitat on the southern end of the marsh managed by the state. A few observations were made on the federal refuge. About one-half of the state marsh is open to public waterfowl hunting in fall. The entire state area is heavily trapped for muskrats by private trappers on a 50–50 share-trapping basis. Length of the trapping season is regulated by the harvestable surplus of muskrats. Raccoons and mink (*Mustela vison*) are trapped throughout the muskrat season.

Before Horicon Marsh was drained for agricultural exploitation, the area produced large numbers of muskrats and ducks (Truax and Gunther, 1951). From 1910 to 1920 drainage interests dug a main ditch through the center of the marsh with twenty-two connecting lateral ditches. These ditch-banks were rapidly invaded by cottonwoods (*Populus deltoides*), willows (*Salix* sp.), various shrubs, and grasses. In 1930 the public requested that the state and federal governments purchase and reflood the marsh. This was accomplished by 1944.

The state marsh has about thirty-six islands ranging in size from one to approximately 160 acres. The predominant cover on the small islands is aspen (*Populus tremuloides*), willow, sumac (*Rhus* sp.), grape (*Vitis* sp.), and various grasses. Some of the larger islands have well-stocked stands of hardwood timber. Figure 1 is a map of the state marsh. Cattails (*Typha latifolia* and *T. angustifolia* or hybrids), bulrush (*Scirpus validus* and *S. fluviatilis*), bur reed

[1] This study is a contribution from the Pittman-Robertson Fur Research Project (15-R) of the Wisconsin Conservation Department. Harold A. Mathiak, fur project leader, Wayne C. Truax, former manager of the state marsh, and Ralph C. Hopkins and Laurence R. Jahn of the waterfowl research project, contributed many valuable suggestions. Harold D. Hettrick, Alan J. Rusch, Arlyn F. Linde and John Dreymiller of the fur project contributed many important field observations. I am indebted to Dr. William Elder of the University of Missouri and Dr. Joseph J. Hickey, University of Wisconsin, for critically reviewing the manuscript.

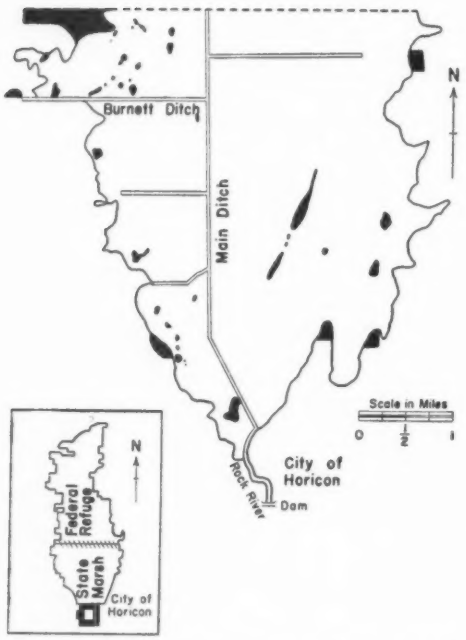

FIG. 1. The state portion of Horicon Marsh. Islands and woodlots are in black. Ditches are shown by parallel lines. The solid exterior line marks the boundary between the marsh and the upland.

(*Sparganium eurycarpum*), and bluejoint (*Calamagrostis canadensis*) are the dominant emergent plants in the marsh.

METHODS

CENSUS. Two methods were used to estimate the raccoon population on the marsh. The number of active raccoon ground and tree dens on 80 per cent of the marsh area were counted in March, 1950. The total population on this part of the marsh was computed by assuming an average of two raccoons for each occupied ground or tree den. Although dens may not average exactly two raccoons each, this assumption seemed to be the most reasonable since work by Steuwer (1943) has shown that young raccoons often den in groups of two's and occasionally three's. On the remaining 20 per cent of the marsh, raccoon population was estimated from the general abundance of tracks in snow. This portion had fewer raccoons.

The estimated spring population in 1950 was probably within 30 per cent of the actual population. The fall population in 1949 was then computed by adding the 1950 spring population figure and the number killed by hunters and trappers during the 1949–50 season. The fall population estimate for 1949 was therefore a minimum figure because over-winter mortality was not considered.

FOOD HABITS. Food habits were studied by collecting scats along ditch-banks and on muskrat houses. Food items in dried scats were tallied by volume and frequency.

RESULTS AND DISCUSSION

RACCOON POPULATIONS. Estimated raccoon populations for 1949 and 1950 are shown in Table 1. In the spring of 1950 the marsh had an estimated 81 raccoons, or 5.8 per square mile. Since 29 were killed by hunters and trappers on the marsh in the 1949–50 open season, the preceding fall population was 110, or 7.8 raccoons per square mile. Hunting, under permit, occurred in November and December along the marsh edge. The Burnett Area mentioned in Table 1 extends north from Burnett Ditch to the federal line and east to the Main Ditch (Fig. 1). This section of the state marsh, about 1300 acres, is well interspersed with wooded islands and is surrounded by upland and ditch-bank on three sides. This mixture of upland and marsh makes the best raccoon habi-

TABLE 1.—RACCOON HARVEST AND POPULATION DENSITY ON THE STATE-OWNED PORTION OF HORICON MARSH

Year	Portion of Marsh	Number Trapped	Number Shot	Population		No. per Sq. Mile	
				Fall*	Spring	Fall*	Spring
1946.....	Entire	40	Unknown	..	..	..	..
1947.....	Entire	12	Unknown	..	..	..	..
1948.....	Entire	33	Unknown	..	..	..	..
1949.....	Entire	18	11	110	..	7.8	..
1950.....	Entire	26	25	..	81	..	5.8
1949.....	Burnett Area	4	0	42	..	20.7	..
1950.....	Burnett Area	5	0	..	38	..	18.7

* Minimum estimate only.

tat on the state marsh, as shown by the density data in Table 1.

Table 1 also shows the number of raccoons trapped and shot from 1946 to 1950. Although there are large fluctuations in the kill from year to year, it is evident that the marsh had a large population prior to 1946 since 40 were trapped in the fall that year. These kill data also indicate that the marsh carried a good raccoon population from 1946 to 1950. Hence food and denning habits of raccoons studied in 1949 and 1950 were not temporary phenomena resulting from a population increase during the two years.

DENNING HABITS. After investigating all large trees on the state marsh, I found only three hollows suitable for permanent raccoon dens. In the spring of 1950, approximately 90 per cent of the estimated 81 raccoons used ground dens on islands or in ditch-banks. About 5 per cent denned in frozen muskrat houses, and about 5 per cent in three hollow trees. In March, 1950, one raccoon was found denning in a peat pocket formed by buckling action of ice. Brown and Bellrose (1943) also reported extensive use of bank dens by raccoons on Lake Chautauqua Refuge in Illinois. However, Bennitt and Nagel (1937) reported use of ground dens by raccoons as uncommon in Missouri.

It is possible that ground dens used by raccoons were dug by other animals. If raccoons do not dig their own ground dens, raccoon populations in habitat deficient in den trees may be limited by a lack of hole-diggers such as red fox (*Vulpes fulva*), skunk (*Mephitis mephitis*), woodchuck (*Marmota monax*), and badger (*Taxidea taxus*).

Raccoons that denned in muskrat houses dug holes in the sides of the houses large enough to crawl inside. Generally, muskrat houses over three and one-half feet in diameter were selected for temporary or permanent winter dens.

During the summer, raccoons often slept in *Calamagrostis-Carex* marsh, denned in or on muskrat houses or inside artificial wood duck boxes of wooden construction with an elliptical hole $3\frac{1}{2}$ x $4\frac{1}{2}$ inches in the front. The boxes were set on steel fence posts and were often surrounded by trees or shrubs.

Widespread use of ground dens by raccoons on the marsh would indicate

that tree dens are not essential for carrying high raccoon populations. Thus the assumption by Bennitt and Nagel (*op. cit.*) and by Steuwer (*op. cit.*) that lack of tree dens limits raccoon populations is not true for Horicon Marsh. Recent increase of raccoon populations in many parts of the country would also indicate that tree dens are not a limiting factor at present. Artificial denning boxes for raccoons therefore are not necessary.

HABITAT AND COVER TYPES USED. Raccoon scats and sign were observed one or more times in all portions of the marsh and at all seasons. Ditch-banks were especially well travelled during spring, summer, and fall. Many scats were found in summer on muskrat houses in *Typha-Scirpus* cover up to one-quarter mile from the nearest dry land. A raccoon litter was found in 1949, 1,000 feet from dry land on top of a muskrat house. On two occasions, raccoon sign was observed one-eighth and one-quarter mile from dry land in October and November in marsh interspersed with open water and emergent cover, with water two to five feet deep throughout. Since Horicon Marsh freezes over about mid-November, it is apparent that raccoons swim long distances in cold water. Any general evaluation of the biological effect of raccoon predation on Horicon Marsh must consider the entire marsh and not merely a narrow strip of marsh adjacent to upland edge.

FOOD HABITS. During 1949 and 1950, I analyzed 390 raccoon scats, (Table 2). Three-hundred eighty-six of these scats represent the food eaten by marsh raccoons from March 20 through October 9. The two years' data were combined. Only fresh scats were used so that the month in which the scat had been dropped could be determined. As indicated in Table 2, I also analyzed twelve raccoon stomachs turned in by trappers and hunters in November, 1949, and January, 1950. Four scats collected in late October are tallied with the stomachs.

Crayfish (*Cambarus* sp.) were the staple food of raccoons on the marsh from March to October. Muskrat kits were the next most important food item, comprising about one-third of the summer diet of raccoons. Adult muskrats were taken in fair numbers only during March and April and in late fall. Various species of fish were taken throughout most of the year. Grapes were an important fall food, while corn (*Zea mays*) was heavily utilized in fall and spring.

To evaluate the vulnerability of prey to raccoons, the relative abundance of major food items must be considered. Muskrat kits on Horicon Marsh are most commonly found from May to July and are present in smaller numbers during August and September (Dorney 1952). A raccoon captures muskrat kits by digging a hole six to twelve inches in diameter into the side of a muskrat house. Often the tail, intestinal tract, and various bones of the kits are left on the muskrat house. In some cases muskrat houses are abandoned by the adults, leaving partially eaten kits and large unplugged holes as evidence of raccoon predation. More typically, adult muskrats rebuild their molested lodges, thus obliterating sign of raccoon damage. Repair of damaged lodges makes it difficult to quantitatively evaluate raccoon predation on muskrat kits from a cursory examination of a marsh in summer. Holes made by mink in muskrat houses

TABLE 2.—FOOD HABITS OF HORICON MARSH RACCOONS, MARCH TO JANUARY

	March 20-April 30		May-June		July-August		Sept.-Oct. 9		Oct. 26-Jan. 2
Number Scats	41		95		98		152		4
Number Stomachs	..		..		..		...		12
	Per cent		Per cent		Per cent		Per cent		Per cent
	Vol.	Freq.	V	F	V	F	V	F	F
Muskrat, kits	..	..	27	40	34	35	9	9	..
Muskrat, adult	12	20	6	6	1	2	1	2	12
Mouse (*Cricetidae*)	3	10	6	11	tr	2	tr	1	..
Rabbit (*Sylvilagus floridanus*)	1	5	..	..	..	..	tr	1	..
Duck, adult	..	..	tr	1	..	..	tr	1	12
Coot & gallinule, adult	3	7	1	2	..	..	..	..	12
Goose, adult (*Branta canadensis*)	4	2	..	..	..	..	..	..	..
Ducklings (Anatidae)	..	..	tr	1	..	..	..	..	..
Eggs, duck	..	..	2	7	tr	3	tr	1	..
Eggs, coot & gallinule	..	..	4	4	1	1	..	..	..
Unknown bird	tr	5	1	7	1	5	1	5	..
Unknown eggs	..	..	1	6	..	..	..	..	..
Crayfish	31	49	28	52	31	64	16	61	6
Fish	9	20	9	17	2	3	13	22	25
Frogs	..	..	2	1	..	..	..	..	..
Snails	2	2	1	4	3	7	10	47	..
Insects	tr	7	4	27	tr	16	tr	5	..
Mussels (*Pelecypoda*)	..	..	tr	1	tr	1	..	..	..
Corn	35	39	6	8	1	1	3	11	50
Oats	..	..	..	..	tr	1	..	..	..
Acorns (*Quercus* sp.)	tr	2	..	..	..	..	6	9	..
Grapes	..	..	..	..	3	8	35	60	..
Cherry, plums (*Prunus* sp.)	..	..	..	..	9	10	2	14	..
Dogwood (*Cornus* sp.)	..	..	tr	1	9	10	tr	1	..
Raspberry (*Rubus* sp.)	..	..	..	..	5	19	..	..	..
Elderberry (*Sambucus* sp.)	..	..	..	..	..	..	3	3	..
Apple (*Pyrus* sp.)	..	..	tr	1	..	..	1	1	..
Grass	tr	2	tr	4	..	..	tr	2	..
Unknown	..	..	2	3	..	..	..	..	..
	100		100		100		100		

are about three to four inches in diameter and are thus differentiated from those made by raccoon. No coyotes are known to occur on Horicon Marsh.

By measuring the guard hairs and noting the bone and toenail-size of muskrat kits in scats, it was possible to estimate age of kits eaten. About 90 per cent of muskrat kits taken by raccoons were less than 20 days of age. Almost no remains of kits more than 30 days of age were observed in scats. Five musk-

rat litters varying in age from 4 to 20 days were found freshly killed by raccoons in the marsh. The dead kits were aged by means of tail length and weight criteria developed from a study of muskrat growth (Dorney *op. cit.*). Thus both sources of data indicated that muskrats over 20 days of age were not vulnerable to raccoons. After 20 days of age, muskrat kits become difficult to catch due to their ability to swim rapidly and stay under water for long periods. Muskrat kits in bank burrows are probably not vulnerable to raccoons. No cases of raccoons digging into muskrat bank dens were found. Low incidence of adult muskrats taken during the summer would indicate that adults were not very vulnerable to raccoons because muskrat breeding densities as high as two to three per acre were not uncommon on the state marsh in the summers of this study. High frequency of adult muskrats in March and April scats probably resulted from a carry-over from frozen carcasses.

Crayfish and frogs (*Rana* sp.) were generally abundant along ditch-banks and islands from the end of April to October. Low incidence of frogs in scats is hard to explain since they were extremely abundant and were readily eaten by penned raccoons. Hamilton (1940) also recorded a low incidence of frogs in raccoon scats on a marsh area where frogs were abundant.

Bird nests were abundant on the marsh from May to August but bird eggs were unimportant in the summer raccoon diet. Low incidence of duck eggs in raccoon scats must be interpreted in terms of total breeding duck populations. Total density of breeding dabbling ducks in 1947 was estimated at 30–36 pairs per square mile (Hopkins 1947). Breeding populations of diving ducks are low (Hopkins *op. cit.*). It was the opinion of Hopkins (*in litt.*) that no marked change in density of breeding ducks had occurred between 1947 and 1950. Since the marsh had an average of about 6 raccoons per square mile in the spring of 1950, this would mean that each raccoon would have an average of only 5–6 pairs of breeding ducks for potential predation. Thus only a small fraction of their diet could be duck nests. However, duck eggs occurred in 7 per cent of the May-June scats, indicating that duck nests are quite vulnerable to marsh raccoons. A study conducted by Arlyn Linde in 1952 on dredged ditches on Horicon Marsh showed that out of 24 duck nests, raccoons apparently destroyed 9 (Mathiak 1953). If duck nests observed on muskrat houses in 1950 are added to this total (1 out of 5 destroyed by raccoons), average loss for the two years is 34 per cent. This estimate substantiates the food-habits data by showing that raccoons can be efficient duck-nest predators.

Corn was utilized by raccoons in upland game food-patches in early fall, winter, and spring. Green corn was sparingly used, probably due to the abundance of berries and crayfish in summer. Fresh berries were abundant from July to October and were an important part of the diet when available.

The waterfowl hunting season opened on October 14 in 1949 and 1950, thereby making a large number of crippled ducks and coots (*Fulica americana*) available to predators. Adult coots and gallinules (*Gallinula chloropus*) were often hard to separate in scats and were therefore combined in Table 2. Most gallinules

migrate before the hunting season and were probably absent in the October 26–January 2 scat and stomach sample. The combined frequency of 24 per cent for ducks and coots in the October 26–January 2 sample probably represents predation on waterfowl crippled by hunters. Studies by Yeager and Rennels (1943) and Yeager and Elder (1945) have shown that the percentage of waterfowl in raccoon scats rises sharply after the beginning of hunting season.

The regular muskrat trapping season opened on November 1 in both years. Trapped muskrats were therefore available to raccoons in large numbers until freeze-up about mid-November, after which the trappers made all their sets under the ice. Occasionally a muskrat caught in a trap under ice will chew a large hole in its feeder house in an attempt to escape and will in this way become vulnerable to predators. Occurence of muskrats in 12 per cent of raccoon stomachs and scats collected from late October to January (Table 2) probably represented predation on muskrats caught in steel traps.

Thus in comparing food habits with availability, only muskrat kits over 30 days old, adult muskrats in summer, frogs and green corn were not utilized in accord with their relative abundance.

SIGNIFICANCE OF KIT PREDATION. The only portion of the state marsh that indicated a possible reduction in muskrat productivity through raccoon predation on muskrat kits was a 107-acre trapping area located north of Burnett Ditch (Trapping Area 6). In the fall of 1950 this area had an age ratio in the harvest of 1.8 young per adult female as compared with an average of 4.9 young per adult female for eight other trapping areas (Mathiak 1951). Sex ratio of immatures and adults was normal in Area 6. As pointed out by Mathiak (*op. cit.*), Area 6 showed a great deal of muskrat-breeding-house molestation by raccoon. Since I estimated the 1950 spring raccoon density in the Burnett Area to be about 19 per square mile (1 per 34 acres), it is not unreasonable to assume that the low fall age ratio of muskrats found in Area 6 may have been the result of excessive raccoon predation. House molestation without necessarily catching kits may also cause kit mortality since a nursing muskrat litter may be scattered and/or moved by the adult when a breeding house is disturbed (Dorney *op. cit.*). It is possible that light raccoon predation on kits may in many cases be compensated for by higher survival of the remaining kits. However, in Area 6 evidence indicated that raccoon predation was so intensive that any compensation was insignificant.

Importance of muskrat kits in the summer diet of raccoons on Horicon Marsh is apparently not representative of other areas. Hamilton (*op. cit.*) analyzed 163 raccoon scats collected in July and September from Montezuma Marsh in New York. Muskrats (age not specified) occurred in less than 8 per cent of these scats. However, muskrats (primarily kits) were present in about 50 per cent of the mink scats collected at the same time, indicating that young muskrats were available on the marsh. Apparently the raccoons had not learned to catch muskrat kits, or abundance of other foods resulted in selective predation.

Wilder, Cofer and Beck (1951), working on a muskrat marsh in Delaware, recorded muskrats in only 9 per cent of

74 scats covering the period from September, 1949, through June, 1950. Most muskrat remains appeared in winter scats. Harris (1952) analyzed 551 raccoon scats collected on Maryland marshes and found that muskrats occurred in 19 per cent. Forty-four per cent of muskrat remains in these scats were muskrats half grown or smaller. However, these two papers do not state what percentage of the scats were collected during the muskrat breeding season; hence it is not possible to compare their results with the high incidence of muskrat kit predation found in this study. Both of these papers also state that raccoons dig holes in muskrat houses to catch small rodents. This feeding habit was not observed on Horicon Marsh. All evidence indicates that raccoons are looking for muskrat kits when they dig holes in muskrat houses on Horicon Marsh. When future studies have analyzed marsh raccoon food-habits data by monthly periods, the national importance of raccoon predation on muskrat kits can be evaluated with more certainty.

RACCOON DAMAGE TO TRAPPED MUSKRATS. Raccoons often eat muskrats caught in steel traps (Lay 1945). This results in a financial loss to trappers because the damaged fur is usually unsalable. During the 1949–50 trapping season (November through January), the hides of seventy-one trapped muskrats were totally ruined by raccoons, and six were partially damaged. Muskrat pelts damaged by mink and opposum (*Didelphis virginiana*) were differentiated from raccoon-damaged pelts by track sign and by the portion of the carcass eaten. No cases were recorded when there was some doubt as to the predator involved. In the 1950–51 trapping season (November through March), only ten muskrat hides were ruined by raccoons. Harvest records for raccoons in 1949 and 1950 (Table 1) indicate that their population in the two years was probably about the same. Muskrat population and trapping pressure was also stable. Therefore, some other reason must have caused the decline in pelt damage in 1950–51.

It might be postulated that an increase in crippled ducks and coots in 1950 could account for some of the decrease in pelt damage, since waterfowl make up an important part of the fall diet (Table 2). Actually about twice as many ducks and coots were crippled in the first half of November in 1950 as in 1949, determined by a hunters' check on the main ditch (Hopkins 1950, 1951). Since about 60 per cent of the pelt damage occurred in the first half of November in both years, the increased crippling rate in November, 1950, may have been a factor in reducing pelt damage that year.

Also, average temperatures during November, December, and January in 1950–51 were much lower than in 1949–50. Over six times as much snow fell during these three months in 1950–51 as in the previous year. Steuwer (*op. cit.*) has shown that low temperatures and snow inhibit raccoon activity. Thus both crippling rates and unfavorable weather in 1950–51 probably caused the decrease in raccoon damage to trapped muskrats.

Since neither fall climate nor crippling loss is controlled by the marsh manager, two alternatives for reducing pelt damage are suggested. The largest share of the pelt damage in 1949 occurred in the marsh adjacent to islands where rac-

coons were isolated from the corn food-patches on the upland. Corn could be placed on these wooded islands during the first part of November, thereby relieving predation on muskrats. The alternative would be to reduce the raccoon population.

SUMMARY

Ecology of raccoons in marsh habitat was studied during 1949 and 1950 on the state portion of Horicon Marsh, near Horicon, Wisconsin. During the spring of 1950 the area had an estimated population of 5.8 raccoons per square mile. About 90 per cent of these raccoons used ground dens in the spring of 1950. The shortage of tree dens on the marsh was not a limiting factor for the population.

Analysis of 390 scats and 12 stomachs showed that crayfish and muskrat kits were the principal foods eaten during the summer. Evidence indicated that a high raccoon population may be capable of causing a severe loss of muskrat kits. Corn was an important food during fall and spring. Various berries were major dietary items in fall. Ducks crippled during the hunting season and muskrats caught in steel traps were also important fall foods.

Raccoons ruined pelts of 71 trapped muskrats in the 1949–50 trapping season and only 10 pelts in the 1950–51 season. In 1950, increased crippling of waterfowl in November and lower temperatures with heavy snows throughout the winter apparently caused this reduction in damage to trapped muskrats.

LITERATURE CITED

BENNITT, R. and W. O. NAGEL. 1937. A survey of the resident game and furbearers of Missouri. Univ. of Mo. Studies, Vol. 12, No. 2. 215 pp.

BROWN, L. G. and F. C. BELLROSE, JR. 1943. Use of nesting boxes for wood ducks by other wildlife. Jour. Wildl. Mgt. **7**: 298–306.

DORNEY, R. S. 1952. Muskrat growth and litter production. M.S. Thesis, Univ. of Wis., 48 pp.

HAMILTON, W. J., JR. 1940. The summer food of minks and raccoons on the Montezuma Marsh, New York. Jour. Wildl. Mgt. **4**: 80–84.

HARRIS, V. T. 1952. Muskrats on tidal marshes of Dorchester County. Publ. No. 91, Chesapeake Biological Laboratory, Solomons Island, Maryland. 36 pp.

HOPKINS, R. C. 1947. (Waterfowl management research.) Wisconsin wildlife research, P-R quarterly progress reports. **6**: 14–70.

———. 1950. (Waterfowl management research.) Wisconsin wildlife research, P-R quarterly progress reports. **9**: 9–70.

———. 1951. (Waterfowl management research.) Wisconsin wildlife research, P-R quarterly progress reports. **10**: 25–135.

LAY, D. W. 1945. Muskrat investigations in Texas. Jour. Wildl. Mgt. **9**: 56–76.

MATHIAK, H. A. 1951. (Wisconsin fur research.) Wisconsin wildlife research, P-R quarterly progress reports. **10**: 168–176.

———. 1953. Experimental level ditching for muskrat management. Tech. Wildl. Bull. No. 5, Wis. Conservation Dept. 35 pp.

STEUWER, F. W. 1943. Raccoons: their habits and management in Michigan. Ecol. Mono. **13**: 203–258.

TRUAX, W. C. and L. F. GUNTHER. 1951. The effectiveness of game management techniques employed on Horicon Marsh. Trans. N. A. Wildl. Conf. **16**: 326–330.

WILDER, N., H. COFER, and R. BECK. 1951. The marsh raccoon as a competitor of the muskrat. Delaware Board of Game and Fish Comm., Dover, Delaware, 5 pp., mimeo.

YEAGER, L. E. and W. H. ELDER. 1945. Pre- and post-hunting season foods of raccoons on an Illinois goose refuge. Jour. Wildl. Mgt. **9**: 48–56.

———. and R. G. RENNELS. 1943. Fur yield and autumn foods of the raccoon in Illinois river bottom lands. Jour. Wildl. Mgt. **7**: 45–60.

Accepted for publication April 14, 1953.

A STUDY OF THE FOOD RELATIONS OF THE LEAST CHUB, *Iotichthys phlegethontis* (COPE), USING RADIOACTIVE PHOSPHORUS

Robert C. Pendleton and Earl W. Smart

Department of Vertebrate Zoology, University of Utah, Salt Lake City

This study was undertaken to perfect a method for accurate food-chain determination with radioactive isotopes. It was also designed to determine some of the food bases for the cyprinid fish, *Iotichthys phlegethontis*, and to determine the role of this fish in mosquito predation as reported by Rees (1945. Proc. 32nd Ann. Meet. N. J. Mosquito Exterm. Assoc: 211—216).

These small fish, which seldom exceed $2\frac{1}{2}$ inches total length, were captured in Big Cottonwood Creek near Salt Lake City with a fine-mesh seine, and put into five-gallon milk cans with a minimum amount of handling. The milk cans had been filled with samples of water from the same stream along with considerable quantities of plants and animals from the stream bottom. This was done to simulate stream conditions when the organisms were transferred to the laboratory.

A stainless steel constant-temperature tank two feet deep, twenty-two inches wide and approximately five feet long was set up to maintain the temperatures found in the stream. The tank was lined with Tygon paint to reduce contamination of the tank wall by the radioisotopes employed. The temperature was maintained at a constant 58°F. by passing cold water through 200 feet of half-inch copper tubing which was wrapped around the outside of the tank and insulated with glass wool.

The tank was aerated through a filtered line using a stone air-breaker. To avoid possibility of death to fish before the experiment could be completed, the tank was disinfected with an aqueous solution of potassium permanganate (50 ppm) to remove fungi and prevent algal bloom. When the tests were ready to be made, the fish were removed to one-gallon jars and four-gallon aquaria that were suspended in the constant temperature tank, but kept separate from the main water supply to reduce the likelihood of radioactive contamination. Water temperature within these separate tanks was within 2°F. of the constant temperature tank.

Radioactive phosphorus (P^{32}) was introduced into gallon jars containing the food species but excluding the fishes. The concentration of P^{32} in these containers was .2 microcurie per milliliter ($\pm$ 15 per cent). The food species were allowed to remain in this solution for 24 hours, after which the radioactive solution was removed by screening, and the animals repeatedly washed in water from the original stream until samples revealed no more than 10 per cent radioactivity above background. After having been washed, a representative sample of the radioactivity-labelled species, usually from 20 to 25 individuals, was dehydrated, ashed, and counted. From this basic count an average was calculated, which, along with the variation

in the group, was used to determine quantitative data as to numbers of prey species taken by fish.

The food species used in this series of tests include the small water flea, *Hyalella knickerbockeri* Bate, the ostracod, *Herpetocypris chevreuxi* (Sars), and mosquito larvae, *Aedes niphadopsis* DeGare.

After washing, each of the food species and the fish were put together in four-gallon aquaria which also contained representative food base material taken from the bottom of Big Cottonwood Creek. The fish and food species which had been labelled were left together for 24 hours, after which the fish were removed, ashed, and counted.

Prior to ashing the fish, an attempt was made to determine whether or not these fish could be identified in the field with a battery-operated beta-gamma survey meter. Checks were made on the fish with such a meter to determine accuracy of field determinations. Although highly successful in actually locating individual fish that had taken labelled organisms, the results obtained were not accurate. However, it does indicate that a speedier method can be made available for such non-detailed studies.

In the first test, fry of *Iotichthys*, less than an inch long, were employed in order to ascertain whether or not extremely small organisms could be traced in such tiny fishes. In this experiment ostracods of the genus *Herpetocypris* were placed in a solution of P^{32} and allowed to remain for 24 hours. The ostracods were then taken out, a sample was counted, and the basic average computed. In this case the ostracods were not ashed since they were so small that the amount of absorption of the beta rays would be negligible. They were, however, carefully desiccated. Counting revealed that these small organisms had an average count above background of 8 counts per minute (cpm) with a range of 6 to 10 cpm.

The ostracods were then placed in gallon jars along with the *Iotichthys* fry and the basic food materials from the bottom of the creek for a period of 24 hours. At the end of that time, five fish were assayed with the following results:

	Iotichthys fry	No. of *Herpetocypris* taken
1.	457 cpm.	87
2.	109 cpm.	14
3.	12 cpm.	1
4.	1 cpm.	0
5.	8 cpm.	1

The average for these representative counts was 115.4 cpm. and obviously one fish, as counted, did not contain an ostracod. There, the 1 count per minute can be attributed to variation in background. The data would indicate the fry have greatly varied abilities to obtain such food, and might give some insight into the reasons for such tremendous mortality among young fish at fry level. Also the data indicate that these small crustaceans are at least a part of the food chain in the fry stage of *Iotichthys*, and that similar small organisms may constitute a reasonably high proportion of the food of such small fish.

The second experiment was carried out with adults of *Iotichthys* using the small water shrimp, *Hyalella knickerbockeri*, as the food species. In this case average count for shrimp at the time they were introduced into the experiment was 362 cpm., with a range of 275 to 542 cpm. After 24 hours, the fish were

ashed at 650°C. The results for six fish are below:

	Iotichthys adults	No. of shrimps taken
1.	1646 cpm.	4 to 5
2.	414 cpm.	1
3.	1608 cpm.	4 to 5
4.	360 cpm.	1
5.	60 cpm.	0—Fragment or absorption of "leakage"
6.	420 cpm.	1

This counting indicates a wide range of variation, but all but one show rough multiples of 362 cpm. It is entirely possible that one of the organisms obtained a dead *Hyalella* which did not accumulate phosphates as rapidly as do living ones. Our experiments showed that the dead *Hyalella* averaged 24.4 cpm. while those alive accumulated 340 cpm. Consequently, Fish Number 5 above may indicate a dead or injured *Hyalella* that was included in the experiment. This experiment indicates that these crustaceans are utilized for food by *Iotichthys* fry, but not as extensively as ostracods.

The third experiment was carried on with adult *Iotichthys*, and the larvae of *Aedes niphadopsis*, a large mosquito common to the Salt Lake Valley. The same procedure was followed as with ostracods and shrimp with the exception that screening of mosquito larvae was found to be impractical. The very soft-bodied organisms were crushed by the flow of water and destroyed. Consequently, they were not screened, but were washed in flowing tap water until virtually all radiation contamination in the water was removed. A screen was placed across the end of the jar in which they had been exposed to P^{32}, and the contents carefully poured into another container until about 99 per cent of the water had been removed. Fresh, clean water was then circulated through a small rubber tube, and the insects were very carefully washed. When wash water coming off the mosquito larvae indicated that it contained less than 10 per cent radioactivity above background, a number of mosquito larvae were removed, carefully blotted to remove excess water, dried, and counted.

The average for this group was 5,165 cpm., with a range between 533 and 8,833. However, this range indicates a great variation that actually did not exist since only two of the larvae counted were below 600 cpm. with the majority of the organisms ranging within a thousand counts of 5,000 cpm. After the fish were allowed to remain in the four-gallon container with the mosquito larvae for 24 hours the following results were obtained for five fish:

	Iotichthys adults	No. of Mosquito larvae taken
1.	22,456 cpm.	4
2.	20,424 cpm.	4
3.	36,658 cpm.	7
4.	22,900 cpm.	4
5.	18,960 cpm.	4

These results indicate that adult *Iotichthys* prey on mosquito larvae, and demonstrates, to a limited extent, their value as predators in mosquito abatement work.

Although brief and incomplete, our findings indicate that the labelling of suspected food species with P^{32} or other beta-emitting radioelements is practical in research on food chains of fishes. Also, preliminary results of such work can be obtained in the field with suitably sensitive portable counters.

Accepted for publication May 5, 1953.

RELATIONSHIP BETWEEN TROUT POPULATIONS AND COVER ON A SMALL STREAM [1]

Marvin F. Boussu

Department of Game, Fish and Parks, Woonsocket, South Dakota

Introduction

The preference of trout for stream areas with protective cover has been recognized for a long time. In England, for example, establishment of artificial "lies", which act as shelter for trout, has been practiced for many years. Greeley (1936), Tarzwell (1937, 1938), and Shetter, Clark, and Hazzard (1946) are among those who have investigated the influence of cover on trout in this country. Their studies have shown that stream improvement, including artificial cover, can lead to an increase in number and size of trout in a given section of stream. Physical improvements used on streams often incorporate shelters along with deflectors, low dams, and other structures. While there is considerable information on the overall effect of stream improvement, little quantitative data have been presented on the extent to which various types of cover affect trout populations. The present study is concerned with the relation between trout populations and (1) the various kinds of natural cover in a small stream, (2) the effect of partial or complete removal of natural cover, and (3) the application of artificial cover to areas naturally devoid of such protection.

The stream selected (Trout Creek) is located about three and one-half miles northeast of Belgrade, Gallatin County, Montana (Fig. 1). It originates primarily in springs and meanders through flat, cultivated and pasture lands for a distance of about four miles before emptying into the East Gallatin River. It is three to five feet in width near its source and widens to approximately 25 feet in the region adjacent to its mouth.

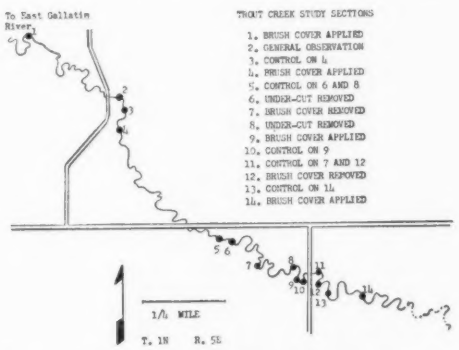

FIG. 1. Trout Creek, showing location of 14 study sections.

Trout Creek remains free of ice throughout the year. The highest water temperature recorded during the study period (June, 1951 – March, 1953) was 63° F. and the lowest, 39° F.

Bank vegetation in the upper third of the stream is composed principally of heavy, alternating growths of sedge (*Carex nebraskensis* and *C. rostrata*) and willow (*Salix* sp.). These two types are about equally abundant in the area. In the middle third there is short-grass

[1] Contribution from Montana State College, Agricultural Experiment Station, Project No. MS-844, Paper No. 300 Journal Series.

pasture with only occasional clumps of willow bordering the stream. The lower one-third, which did not include any study sections, supports a dense growth of willows.

Aquatic vegetation was abundant during certain times of the year. Watercress (*Nasturium officinale*), water speedwell (*Veronica connata*), pondweed (*Potamogeton* sp.), brook grass (*Catabrosa aquatica*), and several species of algae were found. The most important aquatic plants from the standpoint of cover were watercress and a grass-green algae, *Enteromorpha intestinalis*.

Fish present included rainbow trout (*Salmo gairdnerii*), eastern brook trout (*Salvelinus fontinalis*), and brown trout (*Salmo trutta*), with the first two comprising about 98 per cent of the total trout population. On one occasion ten whitefish (*Prosopium williamsoni*) were found. Fresh-water sculpins (*Cottus* sp.), while common, were not included in population figures.

The presence or absence of natural cover, such as overhanging willow, under-cut banks, etc., served as a basis in the selection of 14 study sections. These varied in length from 39 to 98 feet, with an average of 58 feet. Widths ranged from 4 to 21 feet, with an average of 10 feet. Water area, depth, cover, and other physical data were determined for each section. Variations in cover were recorded at the time of each population inventory.

The water areas in each section were classified as either riffle, flat water, or pool. These categories are defined as follows:

Riffle: (1) surface waters choppy, (2) average depth under 8 inches, (3) increased water velocity, (4) bottom of coarse sand or gravel.

Flat water: (1) surface waters smooth, (2) depth variable, (3) moderate velocity maintained through area and flow usually in a straight course, (4) bottom of silt or fine sand.

Pool: (1) surface waters quiet, although some swirls may be evident, (2) comparatively deep—over 12 inches, (3) appreciable reduction in water velocity, often associated with a change in stream course or some obstruction, (4) bottom of silt or clay pan.

Preliminary inventories were taken four times in each section. Cover on eight of the sections was then altered and all sections inventoried three more times. The first four inventories will be referred to as "pre-alteration", and the last three as "post-alteration." Elapsed time from one complete series of inventories to the next varied from 2 to 5 months. Each series was completed as quickly as possible (usually less than a week) to minimize any variations which might arise from fluctuations within the populations. Control sections (those not altered) were usually inventoried the same day as corresponding experimental sections.

Individual sections were isolated with blocking nets during population inventories. Fish were collected (shocked with a 250-watt D. C. generator), weighed, measured, and returned to the water. All fish collected from a section (sculpins excepted) were measured to the nearest 0.1 inch (total length) and weighed to the nearest 0.01 pound. Difficulties in weighing fish during winter operations necessitated application of length-weight data to obtain certain of the weights

used. The fish were arbitrarily divided into three length groups: Legal, 7 inches or over; sub-legal, 4.0 to 6.9 inches; and fingerling, less than 4.0 inches.

APPLICATION OF BRUSH COVER

Cover devices were applied to four sections. These consisted of plank frames with interwoven willow branches (Fig. 2). Their sizes ranged from 15 to

FIG. 2. Artificial brush cover; Section 9.

50 square feet. An attempt was made to simulate natural willow cover in density and position. All devices were installed at least one month before any post-alteration inventories were made in sections where they occurred. The total area of cover applied to the four sections was 155 square feet.

While rate of increase for individual sections varied, there was a marked increase in numbers and pounds of fish in each of the experimental sections. A description of experimental and control sections, and results obtained are as follows:

SECTION 1: This section was primarily flat water, but two pools (maximum depth 24 inches) were present. Overhanging cover was non-existent, but a total of 4.6 square feet of under-cut occurred near one end of the section. This under-cut was believed to be largely ineffective as cover because of the shallow water associated with it. Aquatic vegetation was sparse; only a small patch being present at the head of each pool. The length of this section was 88 feet; average width 163 inches; average depth 12.9 inches. Fifty square feet of brush cover was placed over the pool areas.

The numerical increase in legal-size fish following application of cover was less than either that of sub-legal fish or fingerlings, but the weight increase was several times that of the latter two combined. The increase in weight of legal fish was much greater than in other sections where brush cover was applied; the increase of sub-legal fish smaller. This may have resulted from the presence of three large brown trout which utilized the cover device. Most of the fish were concentrated in pool areas both before and after application of brush cover.

The pre-alteration and post-alteration averages per inventory were as follows: Legal 1.50 (0.29 pounds) to 4.00 (2.97 pounds); sub-legal 7.50 (0.47 pounds) to 12.60 (0.54 pounds), and fingerlings 5.20 (0.05 pounds) to 29.33 (0.25 pounds). Average total pounds per inventory previous to cover application was 0.81; following application this increased to 3.76.

SECTION 4: Previous to alteration, this section was composed entirely of flat water without pools, cover, or under-cut banks. Aquatic vegetation was sparse. It had a length of 51 feet, and an average width of 219 inches.

Average depth was 11.7 inches, but a channel near one edge of the stream averaged about 15 inches in depth. This channel extended through the entire section. Two brush covers having a total area of 45 square feet (14 and 31) were installed at mid-section over the channel.

Following cover application there was an increase in number and weight of fish. No legal fish, and only one sub-legal fish, were found during the pre-alteration inventories. Post-alteration inventories averaged one legal and 4.3 sub-legal fish. Fingerlings increased from an average of 4.25 per inventory to 19.30. The pre-alteration and post-alteration weights were as follows: legal, 0 – 0.44; sub-legal, 0.02 – 0.23; fingerlings, 0.02 – 0.18. Average total pounds per inventory was 0.04 previous to alteration and 0.86 post-alteration.

SECTION 3: Located about 300 yards downstream from Section 4, this section had much the same physical characteristics as the experimental section with the exceptions of a shallower depth (average 9.4 inches), and more abundant aquatic vegetation. No alterations were made in this section.

During the first four shockings, the population corresponded to that in Section 4. Both supported a few small fish during periods of growth of aquatic vegetation. Whereas the experimental section had an average increase in total pounds of 0.82 per inventory, Section 3 changed relatively little with an increase of 0.01 (0.02 – 0.03) pounds.

SECTION 9: Flat water was predominant in this section (approximately 60 per cent), although about 10 per cent of the upper end was riffle area. One pool (maximum depth, 15.0 inches) and 3.0 square feet of under-cut bank were present. There was no overhanging cover. Aquatic vegetation was abundant, especially from late summer to mid-winter. The length of this section was 52 feet; the average width 119 inches; the average depth 6.0 inches. A brush cover of the same size (45.0 square feet) and type as used in Section 4 was placed over the pool area.

The increase in total pounds in this section was twice that of Section 4. The increase in pounds of legal fish was nearly the same in both sections; the larger increase in this section being made up of sub-legal fish and fingerlings. Extensive beds of watercress were present in Section 9, and were practically lacking in Section 4, during the inventories of September and December, 1952. This may account for the larger increase in Section 9. Average numbers and weights of fish per inventory in Section 9 before and after alteration are as follows: Legal, 2.25 (0.31 pounds) to 4.66 (0.79 pounds); sub-legal, 12.00 (0.58 pounds) to 30.00 (1.39 pounds); fingerlings, 19.25 (0.13 pounds) to 40.00 (0.51 pounds). Total pounds per pre-alteration inventory averaged 1.02 and post-alteration, 2.69.

SECTION 10: This section was used as a control for Section 9, and was located about 40 feet upstream from the experimental section. Physical characteristics of the two sections corresponded except that there were two pools in the control section (maximum depths of 16 and 18 inches), and average depth was greater (9.0 inches).

The increase in average total pounds per inventory was 41.5 per cent (1.30 – 1.84) for the control section compared to 163.7 per cent (1.02 – 2.69) for the

experimental section. This increase may have resulted from uprooted aquatic vegetation forming rafts of temporary cover during the September and December, 1952 inventories. These natural covers were 11 and 18 square feet in extent respectively. Several legal fish were known to utilize this shelter.

SECTION 14: This section, located in the uppermost part of the stream, was composed entirely of flat water. No pools were present, but under-cut banks were extensive (22.5 square feet). Heavy growths of sedge overhung the banks from mid-summer to early winter. From the data obtained, it was not possible to correlate this grass cover with fluctuations in the population. This section was 51 feet in length; 45.3 inches in average width, and 5.1 inches in average depth.

In proportion to the area of cover applied, the actual numerical and weight increases were greater in this section than in other sections which received like treatment. The average number of legal fish present per inventory before application of cover was 0.75 (0.13 pounds); after application, 2.00 (0.35 pounds). The number of sub-legal fish increased from 8.13 (0.41 pounds) to 18.74 (1.05 pounds); fingerlings from 9.00 (0.09 pounds) to 13.33 (0.20 pounds). Total pounds per inventory averaged 0.62 previous to cover application, and 1.60 following application.

SECTION 13: This section was the control for Section 14. Physical characteristics of the two were similar with the following exceptions: The control section contained 4 square feet less under-cut; average depth (6.8 inches) was greater, as was average width (75 inches). Bank vegetation, water type, and section length were approximately the same as in Section 14.

The increase in average total pounds per inventory was 9.2 per cent (1.74 – 1.90) in the control section and 158.1 per cent (0.62 – 1.60) in the experimental section. Although there was an increase in total pounds, the control section showed a smaller post-alteration number of fish in all size classes. A brown trout, weighing 2.7 pounds, captured during the December, 1952 inventory accounted for this weight increase. There is no obvious explanation why this section held a consistently higher pre-alteration weight of fish than Section 14, which had 4 square feet more under-cut, although average width and depth were greater.

The increase in total pounds of fish following application of brush cover to four experimental sections amounted to 258.1 per cent. The three sections which were unaltered increased an average of 22.5 per cent. There was an average increase in legals of 0.62 pounds per inventory per 100 square feet of cover applied (Table 1).

REMOVAL OF BRUSH COVER

Overhanging brush cover was removed from two sections, 7 and 12. This was accomplished by chopping the overhang back to bank level at least five weeks before the first post-alteration inventory. Approximately 128 square feet of cover was removed from the two sections. Section 11 was used as a control.

SECTION 7: This section was principally flat water and was located immediately downstream from a short riffle area. Two pools were present; one without cover and the other having

TABLE 1.—BRUSH COVER APPLICATION. AVERAGE NUMBER AND POUNDS (IN PARENTHESES) OF FISH PER INVENTORY, PRE-ALTERATION — POST-ALTERATION

	Experimental Sections 1, 4, 9, 14		Control Sections 3, 10, 13	
	pre-alt.	post-alt.	pre-alt.	post-alt.
Legals	1.12 (0.18)	3.00 (1.14)	2.66 (0.47)	2.66 (0.61)
Sub-legals	6.87 (0.37)	18.16 (0.80)	9.25 (0.47)	6.66 (0.30)
Fingerlings	9.43 (0.07)	25.50 (0.28)	9.66 (0.08)	10.44 (0.13)
All Fish	17.44 (0.62)	45.25 (2.22)	21.58 (1.02)	19.77 (1.25)

about 98 square feet of willow cover. Maximum depth in the open pool was 19.5 inches, and in the covered pool, 18.0 inches. Another willow (19 square feet) overhung shallow water at one end of the section. About 9 square feet of under-cut bank was present under the willow overhanging the pool. Aquatic vegetation was abundant with beds of watercress totaling about 70 square feet in extent being present during both seasons. Length of this section was 59 feet; average width 156 inches, and average depth 9.8 inches. This section was altered by removing the 98 square feet of willow covering the one pool (Figs. 3 and 4).

Previous to the removal of this cover, the average number of legal fish per inventory was 12 (2.37 pounds). Following removal, the average was 4 (0.80 pounds). The number of sub-legal fish decreased from an average of 38.75 (2.08 pounds) to 33.00 (1.26 pounds) per inventory. Fingerlings increased from 48.74 (0.23 pounds) to 88.90 (0.67 pounds). There was a decrease in total pounds from a pre-alteration average of 4.69 to a post-alteration average of 2.73 per inventory.

SECTION 12: Flat water predominated in this section but a short stretch of riffle and one pool with a maximum depth of 21 inches were present. Thirty square feet of brush cover overhung this pool. Approximately 6 square feet of under-cut bank occurred in the upper part of the section. During September and December inventories there was approximately 26 square feet of aquatic vegetation present. This section was 62 feet in length; 76 inches in average width, and 8.0 inches in average depth. Alteration was accomplished by re-

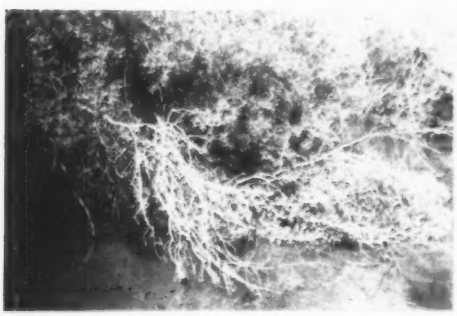

FIG. 3. Section 7 before removal of brush cover.

FIG. 4. Section 7 after removal of brush cover.

moving the 30 square feet of cover overhanging the pool.

The average number of legal fish per inventory previous to cover removal was 10.75 (1.81 pounds). Following cover removal, this dropped to an average of 6.33 (0.94 pounds). Sub-legal fish decreased from an average of 29.75 fish (1.83 pounds) per inventory to 20.33 (1.21 pounds). The number of fingerlings decreased from 12.50 to 11.00, but increased in weight from 0.12 to 0.14 pounds. There was a decrease in total pounds of fish from an average of 3.76 per inventory previous to cover removal, to 2.29 following alteration.

SECTION 11: This section was entirely flat water with the exception of one pool having a maximum depth of 17 inches. There was approximately 70 square feet of willow cover overhanging the pool area, and about 15 square feet of under-cut bank present. Aquatic vegetation was sparse at all times; the maximum area at any time being less than 10 square feet. The section length was 54 feet; average width 79 inches, and average depth 7.7 inches. No alterations were made in this section.

The average number of legal fish per inventory for the first four shockings was 6.75 (1.00 pounds); this increased to 7.33 (1.36 pounds) for the last three shockings. Sub-legal fish decreased from 28.75 (1.62 pounds) to 25.33 (1.45 pounds). Fingerlings also decreased from 14.75 (0.15 pounds) to 12.00 (0.14 pounds). There was an increase in the average total pounds per inventory from 2.77 to 2.95.

Total pounds per inventory increased an average of 6.5 per cent in the control section. The total pounds decreased 40.5 per cent in the sections where cover was removed. There was a weight increase in legal fish of 36.0 per cent in the control section and a decrease of 58.4 per cent in the experimental sections. Legal fish decreased an average of 0.95 pounds per inventory per 100 square feet of brush cover removed (Table 2).

REMOVAL OF UNDER-CUT BANK

Under-cut banks were partially removed from two sections, 6 and 8; Section 5 was used as a control. Removal was accomplished by spading back the overhanging bank to the outermost edge of the stream. The total amount of under-cut removed was about 15 square feet. Under-cut formed by stream action subsequent to removal was allowed to remain. The amount of newly formed under-cut was measured for each of the post-alteration inventories and averaged between them. At least four weeks elapsed before any

TABLE 2.—BRUSH COVER REMOVAL. AVERAGE NUMBER AND POUNDS (IN PARENTHESES) OF FISH PER INVENTORY, PRE-ALTERATION — POST-ALTERATION

	Experimental Sections 7 and 12		Control Section 11	
	pre-alt.	post-alt.	pre-alt.	post-alt.
Legals	11.40 (2.09)	5.18 (0.87)	6.75 (1.00)	7.33 (1.36)
Sub-legals	34.25 (1.96)	26.66 (1.24)	28.75 (1.62)	25.33 (1.45)
Fingerlings	21.77 (0.18)	35.16 (0.41)	14.75 (0.15)	12.00 (0.14)
All Fish	66.12 (4.22)	67.00 (2.51)	50.25 (2.77)	44.66 (2.95)

post-alteration inventories were taken on the sections concerned.

SECTION 6: This section had almost equal amounts of riffle, flat water and pool. The pool occurred at a sharp bend and had a maximum depth of 18.0 inches. No overhanging cover was present. The area of under-cut previous to alteration was approximately 15 square feet. The largest part of this occurred in conjunction with the pool; a smaller amount with riffle and flat water. Aquatic vegetation was moderately abundant. A bed of watercress (about 20 square feet) was present near the upper end of the section from late summer to mid-winter. Several variable small patches of brook grass and pondweed were found in midstream throughout the year. Length of this section was 53 feet, average width 114 inches, and average depth 9.7 inches. Alteration consisted of removing 10 of the 15 square feet of under-cut present.

The change in numbers of fish (average per inventory) before and after alteration was as follows: legal fish decreased from 2.50 (0.70 pounds) to 1.66 (0.32 pounds); sub-legal fish increased from 4.75 (0.25 pounds) to 6.66 (0.26 pounds), and fingerlings increased from 7.25 (0.07 pounds) to 11.00 (0.13 pounds). The decrease in average total pounds per inventory, pre-alteration to post-alteration, was from 1.02 to 0.70. There was an increase in the average number of fish per inventory from 14.50 to 19.33.

SECTION 8: This section was entirely flat water with no overhanging cover. The under-cut bank previous to alteration was about 7 square feet in extent. Aquatic vegetation was moderately abundant (approximately 35 square feet) throughout the year, and was composed principally of brook grass. The length of this section was 39 feet; average width 110 inches, and average depth 5.5 inches. Approximately 5 square feet of under-cut bank was removed.

The change in the fish population per inventory before and after alteration was as follows: Legal fish, 1.25 (0.19 pounds) to 0; sub-legal fish 4.75 (0.23 pounds) to 3.66 (0.12 pounds); fingerlings 12.75 (0.07 pounds) to 13.66 (0.18 pounds). The average total pounds per inventory was 0.48 previous to alteration and 0.29 following alteration. There was also a numerical decrease of 1.43 fish per inventory (18.75 – 17.32).

SECTION 5: This section was entirely flat water with no overhanging cover. Approximately 21 square feet of under-cut bank was present. Aquatic vegetation was moderately abundant throughout. It had a length of 48 feet; average width 120 inches, and average depth 8.5 inches. This section was used as a control and no alterations were made.

The change in numbers and weights of fish per inventory from the first four to the last three inventories was as follows: Legal fish, 3.25 (0.91 pounds) to 3.00 (0.50 pounds); sub-legal fish, 8.25 (0.42 pounds) to 22.00 (0.95 pounds); fingerlings, 11.50 (0.09 pounds) to 23.00 (0.25 pounds). The change in the average total pounds per inventory was from 1.42 to 1.70. The numbers of fish increased from 23 to 48.

The average decrease in pounds per inventory for the experimental sections was 33.3 per cent. The control section increased 19.7 per cent during the same period of time. There was an average decrease of 1.66 pounds per inventory

per 100 square feet of under-cut removed (Table 3).

AQUATIC VEGETATION

While no sections were devoted exclusively to the study of aquatic vegetation as cover for fish, observations and measurements of plant growth were made on several of the sections used in other experiments. Aquatic vegetation appeared to have value as cover both while rooted and after becoming detached. While rooted, plants are extensively utilized as cover, especially by smaller fishes. After breaking loose from the bottom, plants form floating rafts which lodge against overhanging brush or collect in quieter areas of the stream. These were known to be utilized by fish of all sizes.

Watercress appears about July, and as the summer progresses it forms extensive beds in some of the sections. These begin to break up in November or December, and by the latter part of March are almost completely gone. In those sections having extensive beds of watercress, areal abundance was approximately the same for both years (1951–1952). Brookgrass and pondweed were also present in some sections. These plants formed underwater mats which remained quite constant throughout the year.

Combining all sections, the post-alteration inventories showed a higher average number and weight of fingerlings than did those inventories taken prior to alteration. This was probably the result of no post-alteration inventories being taken in July when fingerling populations were low, due to seasonal fluctuation (Holton, 1953), whereas two pre-alteration inventories were taken during this month.

Fingerlings increased (pre-alteration to post-alteration) in all but Section 11. However, it was not possible to correlate these increases with manipulation of cover. In those sections where rooted aquatic vegetation was sparse, fingerlings tended to follow the same population trends as shown by legal fish (Sections 1 and 4). The presence of abundant aquatic vegetation evidently tempered, or even reversed this tendency, as a comparison of Sections 7 and 9 shows. Both of these sections possessed abundant aquatic vegetation. In Section 9 the application of cover was followed by an increase in legal fish (0.48 pounds, average per inventory), and an increase in fingerlings (0.38). In Section 7 the removal of cover was followed by a reduction in legal fish (1.57 pounds, average per inventory), and an increase in fingerlings (0.44). The decrease in legal fish in this section was

TABLE 3.—UNDER-CUT REMOVAL. AVERAGE NUMBER AND POUNDS (IN PARENTHESES) OF FISH PER INVENTORY, PRE-ALTERATION — POST-ALTERATION

	Experimental Sections 6 and 8		Control Section 5	
	pre-alt.	post-alt.	pre-alt.	post-alt.
Legals	1.88 (0.44)	0.83 (0.16)	3.25 (0.91)	3.00 (0.50)
Sub-legals	4.75 (0.24)	5.17 (0.19)	8.25 (0.42)	22.00 (0.95)
Fingerlings	10.00 (0.07)	12.33 (0.15)	11.50 (0.09)	23.00 (0.25)
All Fish	16.63 (0.75)	18.33 (0.50)	23.00 (1.42)	48.00 (1.70)

the largest of all sections; the increase in fingerlings the largest of all sections. There was no apparent effect of rooted aquatic vegetation on the abundance of legal fish.

The use of aquatic vegetation as temporary cover after it had broken loose and formed rafts, was noted on several occasions. Section 10 possessed this type of cover in December, 1952 and again in March, 1953. Several large fish were found utilizing this cover. Section 2 demonstrated the value of free-floating aquatic vegetation as cover. This section contained a deep pool with overhanging willow cover. During the first three inventories, the willow branches which extended into the water were clogged with floating materials—much of which was aquatic plants. This formed a dense, mat-like covering which disappeared sometime between the March and July, 1952 inventories, leaving only the willow branches as cover. The average weight of fish in this section was 5.6 pounds per inventory previous to the loss of this cover, and 1.6 pounds after; a reduction of 71 per cent. No other ecological changes were observed which might account for such a change.

ACKNOWLEDGEMENTS

The writer wishes to acknowledge and extend thanks to Dr. C. J. D. Brown who suggested and gave overall direction to this study, and helped in preparation of the manuscript. Several students at Montana State College gave valuable assistance in collection of field data. Special acknowledgement is given George D. Holton and LeRoy Ellig in this respect. The Montana Fish and Game Department provided equipment for much of the field work and the Montana State College Agricultural Experiment Station gave financial assistance.

SUMMARY

1. A study was made of the relationship of eastern brook trout, rainbow trout, and brown trout populations to cover in Trout Creek, Gallatin County, Montana.

2. Fourteen sections were established as study areas. These sections were selected on the basis of presence or absence of cover features such as overhanging brush and under-cut banks.

3. Fish were collected by shocking and arbitrarily classified into three length groups; legal fish, sub-legal fish, and fingerlings.

4. All sections were inventoried four times prior to alteration (July, December, 1951; March, July, 1952). Cover on eight sections was altered. Five sections were unaltered and used as controls. One section was used for general observations.

5. All sections were inventoried three times following alteration (September, December, 1952; March, 1953). A comparison of pre-alteration and post-alteration populations was made.

6. A total of 155 square feet of brush cover was applied to four sections. The increase in total pounds following this application averaged 1.60 per inventory. The populations in three control sections increased by an average of 0.23 pounds per inventory.

7. A total of 128 square feet of natural brush cover was removed from two sections. The decrease in total pounds of fish per inventory following this removal was 1.71. A control section

increased in total pounds by an average of 0.18 per inventory.

8. Fifteen square feet of under-cut bank was removed from two sections. The decrease in total pounds per inventory following this removal was 0.25. The control section increased in total pounds an average of 0.28 per inventory.

9. Aquatic vegetation appeared to be of value as cover when rooted to the stream bottom and also while free-floating.

LITERATURE CITED

GREELEY, J. R. 1936. Progress of stream improvement in New York State. Trans. Am. Fish Soc., **65**: 316–321.

HOLTON, G. D. 1953. A trout population study on a small creek in Gallatin County, Montana. Jour. Wildl. Mgt., **17**: 62–82.

SHETTER, D. S., O. H. CLARK, and A. S. HAZZARD. 1946. The effects of deflectors in a section of a Michigan trout stream. Trans. Am. Fish. Soc., **76**: 248–278.

TARZWELL, C. M. 1937. Experimental evidence on the value of trout stream improvement in Michigan. Trans. Am. Fish. Soc., **66**: 177–187.

———. 1938. An evaluation of the methods and results of stream improvement in the southwest. Trans. N. A. Wildl. Conf., **3**: 339–364.

Accepted for publication May 26, 1953.

AGE AS A FACTOR IN ACQUISITION OF PARASITES BY CANADA GEESE

Everett E. Wehr and Carlton M. Herman

U. S. Agricultural Research Service, Animal Disease and Parasite Research Branch, Beltsville, Maryland and
U. S. Fish and Wildlife Service, Patuxent Research Refuge, Laurel, Maryland

That the degree of susceptibility to parasitism varies with age is not a new idea. Age immunity to certain parasites has been recognized in a number of birds and mammals. In general, older animals are refractile to many parasites while younger ones are susceptible. Such age resistance usually is considered to be due to physiological factors, but anatomical changes also are known to be involved. Recent investigations on adult and young Canada geese (*Branta canadensis*) have provided additional information on this subject.

In connection with life history and pathogenicity studies of diseases and parasites of the adult Canada goose along the Atlantic coast, a number of goslings were obtained for experimental purposes. Altogether, 46 goslings, ranging in age from two to eight weeks at time of capture, were received: 29 from the Seney National Wildlife Refuge in Michigan and 17 from the Bear River National Wildlife Refuge in Utah. These birds were made available by the Branch of Wildlife Refuges of the U. S. Fish and Wildlife Service.

Upon their arrival at the Agricultural Research Center at Beltsville, Md., or

the Patuxent Research Refuge at Laurel, the goslings were placed in wire-floored cages. They were supplied with turkey starter mash and succulent green feed.

Within a few days some of the goslings from Michigan became sick and died, or were killed when it was decided that they would not survive much longer. Postmortem examinations showed that most of them were heavily infected with both protozoan and worm parasites, many of the latter being mature or nearly so. Mycotic pneumonia was the cause of death or sickness in two goslings but the others showed no ailment except heavy parasitism. The remaining birds from Michigan and those from Utah were held in confinement and killed at various times for other studies. At the time of autopsy, the species of parasites present in each bird and approximate number of each species were recorded.

Parasites found at autopsy, together with the organs from which they were collected, and the locality in which each bird host originated, are listed in Table 1. Four groups of parasites are represented: Protozoa; Nematoda, or roundworms; Cestoda, or tapeworms; and Trematoda, or flukes.

AGE AT WHICH GOSLINGS ACQUIRE PARASITES

It is evident that many of the geese acquired parasites early in life. A list of parasites collected from eight birds from Michigan which died or were killed soon after their arrival at one of the research

TABLE 1.—LIST OF PARASITES FOUND IN 29 GOSLINGS FROM MICHIGAN AND 17 GOSLINGS FROM UTAH

Parasite	Organs involved	Michigan	Utah
Protozoa			
Eimeria spp.*	Intestine	√	..
Haemoproteus nettionis ♯	Blood	√	..
Leucocytozoon simondi ♯	Blood	√	..
Trichomonas anseri *	Ceca	√	√
Tyzzeria sp.*	Ceca and Intestine	√	√
Nematoda			
Amidostomum anseris *	Gizzard	√	√
Capillaria sp.+	Intestine	√	..
Tetrameres sp.♯	Proventriculus	√	..
Trichostrongylus tenius *	Ceca	√	..
Cestoda			
Drepanidotaenia lanceolata ♯	Intestine	√	√
Hymenolepis sp.♯	Intestine	√	√
Trematoda			
Blood flukes ♯	Blood vessels	√	..
Prosthogonimus sp.♯	Bursa of Fabricius	√	..
Notocotylus attenuatus ♯	Ceca	√	..

√ Parasites present.
* Parasites in which life cycle is direct.
♯ Parasites in which life cycle is presumably indirect.
+ Parasites in which it is uncertain whether life cycle is direct or indirect.

stations previously mentioned and the estimated age of each bird at time of death are given in Table 2.

Oocysts of *Tyzzeria* sp. were present, in some instances in large numbers, in intestines and ceca of five of the eight goslings. Allen (1936) studied development of *Tyzzeria perniciosa* in the domestic duck and observed that the first oocysts appeared in droppings of the birds at the end of the fifth day following inoculation. She reported inflammation of, and hemorrhagic areas throughout, the small intestine in heavy infections. Such birds died within five days after feeding of oocysts. Ducklings one week old were highly susceptible to infection with this coccidium. Canada goose goslings, one to two weeks old, were very susceptible to *Tyzzeria* sp., as shown by the numerous oocysts recovered from the bird which died when 17 days old.

Oocysts of *Eimeria* spp. were seen only in the gosling killed when 56 days old. This bird was reported to be three weeks old at the time of its capture. This was, therefore, an example of an infection acquired early in life that had persisted until death. Later studies showed that three species were present in this bird (Farr, 1953). Moreover, these studies by Farr on the morphology, identity, and life cycles of species of *Eimeria* infecting the Canada goose showed that experimentally inoculated domestic geese passed oocysts in droppings five to nine days following inoculation, the exact time depending upon the species involved.

Chernin (1952) showed that the incubation period of *Leucocytozoon simondi* in the domestic white Pekin duck in Michigan was between 10 and 15 days. Ten days after exposure he observed parasitemia in several ducks exposed for six days. In our studies *L. simondi* was observed in peripheral blood as early as three weeks after hatching. This would suggest that these goslings obtained their infections during the first week of life.

TABLE 2.—INCIDENCE OF PARASITES IN 8 GOSLINGS FROM MICHIGAN THAT DIED SOON AFTER CAPTURE

Parasites	Age of goslings in days							
	17	21	23	28	30	34	47	56
Eimeria spp.	..	..	..	..	..	..	..	√
Leucocytozoon simondi	..	√	√	√	..	..	..	..
Tyzzeria sp.	√	√	√	√	..	..	√	√
Amidostomum anseris	..	..	..	..	..	√	√	√
Tetrameres sp.	..	..	√	..	√	√	√	√
Trichostrongylus tenuis	..	..	..	..	√	..	..	..
Drepanidotaenia lanceolata	√	..	..	..	√	..	..	..
Hymenolepis sp.	..	√	√	√	..	√	..	√
Blood flukes	..	..	..	..	..	..	√	..
Notocotylus attenuatus	√	√	√	√	√	√	√	..
Prosthogonimus sp.	..	..	√	..	..	√	..	..

√ Parasites present.

Several specimens of worm parasites that were recovered from these goslings were mature or nearly so. This would suggest that either birds picked up their infections very soon after hatching or that rate of development of parasites is relatively rapid. The rate of development within the body of the final host for most of the worms of the Canada goose is not known. However, that of a number of closely related species in other hosts is sufficiently well known to enable one to arrive at close approximations. Investigations (Jones, 1929) showed that the tapeworm, *Hymenolepis carioca*, of the domestic fowl requires from two to three weeks to reach the egg-laying stage after its ingestion by the avian host. Assuming that the closely related tapeworm, *Drepanidotaenia lanceolata*, of the Canada goose has a somewhat similar developmental period, the 17-day-old gosling must have ingested the cysticercoids within a few days following hatching. Five specimens of this tapeworm were obtained from this bird, one of which measured 80 to 90 mm. long and contained well-developed sex organs but no eggs. This gosling also harbored a large number of cecal flukes, *Notocotylus attenuatus*. According to Herber (1942), the cyst or infective stage of a closely related fluke, *N. stagnicolae*, a parasite of the domestic fowl and wild ducks, reaches maturity in the definitive host in about ten days. Therefore, it can be assumed that the gosling acquired the cysts of *N. attenuatus* during the first week of life.

The proventricular worm, *Tetrameres* sp., was not encountered in either of the two birds dying on the 17th and 21st days, respectively, after hatching. However, a great many immature forms of these dimorphic worms, the males of which are long and threadlike and the females large and globular-shaped, were present in the glandular stomach of the gosling which died on the 23rd day after hatching. The female worms which had already entered the glands of the proventriculus were only partly grown. The ovarian and uterine coils of expressed female worms were still discernible through the colorless body, and the middle portion of the body was just beginning to swell slightly. Specimens of this parasite were also found in goslings which died at ages of 30 and 34 days. Full-grown males were collected from the surface of the mucosa, and bright red females were expressed from the glands of the proventriculus; none of the latter, however, contained mature eggs. In the bird dying at approximately 56 days of age, uterine ducts of female worms were filled with fully developed eggs, some of which contained partly-developed embryos. Cram (1936) fed infective larvae of *Tetrameres americana* to chickens. When these birds were autopsied 19 to 25 days later, she found fully-grown males, but females had not yet attained full growth and did not contain eggs. By the 29th day after ingestion of infective larvae, female worms for the first time had the bright red color of the mature worm, but it was not until the 45th day after infection that embryonated eggs were observed. One may conclude, therefore, that infective larvae must have been acquired by the goslings from Michigan within the first few days of life.

The gizzard nematode, *Amidostomum anseris*, and the cecal strongyle, *Trichostrongylus tenuis*, have direct life cycles. Our studies indicate that eggs of these

two parasites, already in an early stage of development when eliminated with the feces, contain active larvae within one to two days after leaving the host. Larvae escape from the eggs within the next few days and reach the infective stage in approximately two to three weeks. Specimens of the cecal strongyle, *Trichostrongylus tenuis*, were found for the first time in the gosling dying at the age of 30 days, whereas the gizzard worm, *Amidostomum anseris*, was seen for the first time in the gosling dying at the age of 34 days. However, the presence of thin-shelled eggs, already showing some development, in the intestinal and cecal contents of birds that had died or were killed at a younger age was evidence that adults of both of these worms were present earlier.

The single bird from which a few blood flukes were removed was approximately one month old at the time of its capture. Since this bird was confined in a wire cage indoors from capture until death 17 days later, there was no opportunity for it to acquire cercariae or infective stages of these worms. Infection must have been acquired, therefore, prior to capture.

Specimens of *Prosthogonimus* spp. have been collected from wild birds on a number of occasions. As these parasites normally inhabit the bursa of Fabricius, they are seldom found in adult birds. With atrophy of this structure on the eve of maturity, these flukes are lost or, in domestic fowl, enter the oviduct. However, their existence in the oviduct is supposedly limited to the functional season of this structure which, in most birds, is very short. In the domestic hen, the oviduct may remain functional most of the year, with the result that the sojourn of the parasites may be prolonged.

As a result of the examination of several hundred juvenile and adult Canada geese, captured during the winter months on Pea Island National Wildlife Refuge, off the eastern coast of North Carolina, only one specimen of *Prosthogonimus* was found. The bird harboring this parasite was captured on August 21, 1950. It had remained on the island instead of accompanying the main flock in its spring migration to northern breeding grounds. The age of this bird was not determined, but the fact that it had been on the refuge at least since November, 1949, makes it certain that it was at least one and one-half years old, and may have been older. In contrast to this, one gosling from Michigan yielded 22 specimens of this trematode.

Different species of birds attain sexual maturity at different ages. In the Canada goose, the presence or absence of a bursa of Fabricius in either sex, and the presence or absence of an "occluding membrane" over the opening of the oviduct in the female, have been considered the most reliable characters for separating yearlings from older birds (Hanson, 1949). Hanson stated that absence of a bursa in either sex and possession of an open oviduct in the female is evidence that the goose is at least two and one-half years old. We may conclude that the Canada goose reaches maturity sometime between the second and third years. This indicates that birds older than two and one-half years would be refractory because of absence of normal habitat for *Prosthogonimus*.

Most parasitic infections of the blood can be diagnosed only during a relatively short period. For example, malaria

parasites first appear in the blood soon after birds are infected. They can be detected for a time but then most of them disappear from the blood and reappear in numbers only during relapse. Duration of parasitemia with either *Leucocytozoon simondi* or *Haemoproteus nettionis* in birds received as goslings from Michigan was determined by periodic preparation of blood smears. Peripheral blood smears were procured tri-weekly from ten of the goslings for several months, beginning from date of arrival at the laboratory, and then intermittently on several of these geese throughout fall and winter. The longest period of parasitemia with *L. simondi* was six weeks; in most cases infection could be demonstrated only for a period of less than one month. The longest period of parasitemia with *Haemoproteus* infection was 24 days. These parasites were also observed on a few occasions in blood smears of "juveniles" (8 to 12 months) and nearly mature or mature adult Canada geese captured during winter months.

Levine and Hanson (1953) reported, as a result of examination of 353 Canada geese, a relationship between age of birds and intensity of infection with *Leucocytozoon* and *Haemoproteus*. Out of 76 juveniles (5 to 7 months) 112 yearlings (17 to 19 months), and 165 adults (29 months or more) examined, these authors reported that 21 (27.6 per cent) of juveniles, 6 (5.4 per cent) of yearlings, and 5 (3.0 per cent) of adults were infected with *Leucocytozoon*, while no juveniles, 1 (0.9 per cent) of yearlings, and 4 (2.9 per cent) of adults were infected with *Haemoproteus*. Findings of this study are substantially in agreement with those reported above. As yet there is no explanation for these differences of incidence.

The shortest incubation period observed for coccidia which were isolated from the Canada goose was five days. After feeding viable oocysts of this parasite to domestic geese, a shower of oocysts was detected in feces five days later. Immune response in these experimental infections was similar to that in chicken infections as summarized by Bracket and Bliznick (1950), with only low grade infections evident after the initial course. However, extensive output of oocysts is frequently evident in adult wild birds in North Carolina, as was readily demonstrated by fecal examinations.

The incubation period and duration of cecal trichomonad infections are not known. Hegner (1929) reported transmission per rectum to parasite-free chicks, with an incubation period of only two days. This parasite has been observed in adult geese as well as goslings.

The *Tetrameres* infection is capable of remaining in geese for periods of over one year. Geese kept on wire-floored pens in the laboratory for periods of 14 to 16 months still were infected with large numbers of this parasite. One gosling, two to three weeks old when received from Michigan in June, 1951, was autopsied on April 15, 1952. From 2500 to 3000 female worms were estimated to be present in glands of the proventriculus.

Amidostomum anseris was also still present in the birds after nine months to over a year in captivity, but with fewer worms per bird than in those examined at earlier ages, perhaps indicating that some of these parasites are lost as the birds become older. However, one

Canada goose from Pea Island, a sick, emaciated, mature female sacrificed on March 15, 1951, contained 1,537 specimens of this nematode in the gizzard.

Specimens of the tapeworms, *Hymenolepis* sp., and *Drepanidotaenia lanceolata*, were recovered from the small intestine of 17- and 21-day-old goslings from Michigan. Birds retained in captivity for several months also were shown on autopsy to harbor these parasites. Several specimens of these species of tapeworms were recovered from the small intestine of two birds from Michigan which died or were killed at ages of 163 and 205 days; both of these birds were less than one month of age at capture. These two species of tapeworms were also recovered from goslings received from Utah. *Hymenolepis* sp. was recovered from a bird 195 days old, and *D. lanceolata* from a bird 104 days old. These tapeworms were also found in juvenile and adult Canada geese captured in North Carolina in winter.

GEOGRAPHICAL DISTRIBUTION

The distribution of parasites in the Canada goose may be governed, to a large extent, by life cycles of the various parasites. The monoxenous parasites—those having a direct life cycle—require no intermediate hosts to complete development. Many of these parasites inhabit the intestinal tract. Precursors of the next generation, such as ova of nematodes and oocysts of coccidia, escape with feces of the host. Frequently a period of development on the ground or in the surface soil is required before these reach an infective stage. Coccidia may require only a 24-hour period under proper conditions of moisture and temperature while gizzard worms may require a week or more. Infection usually occurs by ingestion of food contaminated with the infective stage of the parasite.

Many parasites are dependent upon one, or in some cases two, intermediate hosts, usually some invertebrate, for completion of their life cycles. Such parasites are designated as heteroxenous. The intermediate host is essential for perpetuation of the parasite, because following a short growth period within the body of the intermediate host, the parasite is transformed from a noninfective to an infective stage. It is capable of continuing its growth to maturity when it enters a suitable definitive or final host. For example: the lanceolate tapeworm, *Drepanidotaenia lanceolata*, the hymenolepid tapeworm, *Hymenolepis* sp., the cloacal fluke, *Prosthogonimus* sp., and the cecal fluke, *Notocotylus attenuatus*, all presumably utilize some kind of snail, insect, crustacean or other aquatic invertebrate as intermediate host. Although the life history of the proventricular worm, *Tetrameres* sp. of the Canada goose is not known, evidence points to involvement of an intermediate host, since all species of the genus *Tetrameres* whose life histories are known require intermediate hosts. The blood protozoan, *Leucocytozoon simondi*, in ducks is transmitted by bloodsucking blackflies, *Simulium* spp., and another blood protozoan, *Haemoproteus nettionis* is also probably transmitted by a bloodsucking vector.

The distribution of heteroxenous parasites is dependent on the distribution of intermediate and definitive hosts. Presence or absence of any one or more species of these parasites in the Canada

goose from either Michigan or Utah could well be due therefore, to presence or absence of the intermediate host of those species. Until life cycles of these parasites have been worked out and intermediate hosts become known, the importance of distribution of intermediate hosts as a governing factor in distribution of parasites of Canada geese must remain a matter of conjecture.

One might expect the distribution of monoxenous parasites to be governed only by distribution of their hosts. These parasites are more universally distributed in the Canada goose than are heteroxenous species. *Amidostomum anseris* was collected from 6 (35.3 per cent) goslings from Utah and 12 (41.3 per cent) from Michigan; the cecal and intestinal coccidium (*Tyzzeria* sp.) in 14 (48.2 per cent) goslings from Michigan and 1 (5.9 per cent) from Utah; the intestinal coccidia (*Eimeria* spp.) only in 3 (10.3 per cent) from Michigan; and *Trichomonas* sp. in only one bird from each locality. However, studies on older birds from a number of localities demonstrate that these parasites are widely distributed, although the incidence and intensity of infection may vary considerably.

Among the heteroxenous forms, reference to Table 1 shows that the two species of tapeworms, *Drepanidotaenia lanceolata*, and *Hymenolepis* sp. were found in goslings from both areas, whereas *Tetrameres* sp., *Notocotylus attenuatus*, *Prosthogonimus* sp., *Leucocytozoon simondi*, *Haemoproteus nettionis*, and blood flukes were absent in birds from Utah. Postmortem records of parasites collected from goslings showed that parasite infections were usually heavier in birds from Michigan than in those from Utah. The lanceolate tapeworm, *Drepanidotaenia lanceolata*, occurred in 2 (7 per cent) birds from Michigan and 2 (11.7 per cent) from Utah; *Hymenolepis* sp. in 8 (27.5 per cent) birds from Michigan and 3 (17.6 per cent) from Utah; *Tetrameres* sp. in 21 (72.4 per cent), *Notocotylus attenuatus* in 6 (20.7 per cent), *Prosthogonimus* sp. in 4 (14.0 per cent), *Leucocytozoon simondi* in 4 (14.0 per cent) and blood flukes in 1 (3.4 per cent) of the birds from Michigan. None of these latter five species of parasites were present in birds from Utah.

One may speculate still further and say that the absence of this or that particular parasite from birds of one or the other of the two localities may be due to lack of intermingling of birds of the two areas with each other at a time when transmission could occur. However, until a more extensive survey of parasites of young and adult Canada geese from each of these areas has been made, further speculation is useless.

SUMMARY

Examination of 46 Canada goose goslings yielded 14 species of parasites including five Protozoa, four Nematoda, two Cestoda, and three Trematoda. Evidence indicates that goslings acquired most of these infections during their first week of life. Some parasites, *Prosthogonimus* sp., occurred only in younger birds. Others, *Leucocytozoon simondi*, were evident only during the initial course of infection, while still others remained evident in older geese. Parasites with a direct life cycle appeared to be more prevalent than those requiring intermediate hosts. Among 29

birds from a refuge in Michigan, 14 species of parasites were found; while in 17 goslings from a Utah refuge, only five species occurred.

LITERATURE CITED

ALLEN, E. A. 1936. *Tyzzeria perniciosa* gen. et sp. nov., a coccidium from the small intestine of the Pekin duck, *Anas domesticus* L. Arch. Protistenk., **87**: 262–267.

BRACKETT, S., and A. BLIZNICK. 1950. The occurrence and economic importance of coccidiosis in chickens. Lederle Labs. 78 pp.

CHERNIN, E. 1952. The epizootiology of *Leucocytozoon simondi* infections in domestic ducks in northern Michigan. Amer. Jour. Hyg., **56**: 39–57.

CRAM, E. B. 1931. Developmental stages of some nematodes of the Spiruroidea parasitic in poultry and game birds. Tech. Bull. 227, U. S. D. A., 27 pp.

FARR, M. M. 1953. Three new species of coccidia from the Canada goose, *Branta canadensis* (Linné, 1758). Jour. Wash. Acad. Sci. **43**: 336–340.

HANSON, H. C. 1949. Methods of determining age in Canada geese and other waterfowl. Jour. Wildl. Mgt., **13**: 177–183.

HEGNER, R. W. 1929. The infection of parasite-free chicks with intestinal protozoa from birds and other animals. Amer. Jour. Hyg., **10**: 33–62.

HERBER, E. C. 1942. Life history studies on two trematodes of the subfamily Notocotylinae. Jour. Parasit., **28**: 179–196.

JONES, M. 1929. *Aphodius granarius* (Coleoptera), an intermediate host for *Hymenolepis carioca* (Cestoda). Jour. Agric. Res. **38**: 629–632.

LEVINE, N. D., and H. C. HANSON. 1953. Blood parasites of the Canada goose, *Branta canadensis interior*. Jour. Wildl. Mgt., **17**: 185–196.

Accepted for publication May 18, 1953.

EXPERIMENTS AND OBSERVATIONS DESIGNED TO SHOW CARP DESTRUCTION OF AQUATIC VEGETATION

C. W. Threinen and Wm. T. Helm

Wisconsin Conservation Department, Madison

It is contended that carp (*Cyprinus carpio*) are extremely destructive to aquatic vegetation, but the evidence for such a statement is generally circumstantial. In southeastern Wisconsin, where the carp problem is most acute, the necessity of demonstrating such destructiveness under natural conditions became urgent both for research purposes and for education of the public. Experiments performed in 1951 and 1952 were conclusive enough to permit making a preliminary report.

There are a number of references in the literature which relate the scarcity of aquatic plants to carp. In Wisconsin, Cahn (1929) diagnosed the destruction by making observations on a drawndown mill pond which was completely barren of vegetation. Black (1946), in 1944, was the first to carry out a controlled experiment. He divided a small

pond which had grown up to vegetation, introducing carp into one half and leaving the other half as control. Decided destruction of aquatic vegetation was evident after 51 days in the experimental half of the pond. Anderson (1950) described considerable improvement in the growth of aquatic vegetation in a pond in Ohio following removal of rough fish, where, prior to control of rough fish, turbid water and only occasional sprigs of vegetation were found.

The first evidence in this investigation that carp destroy aquatic plants was accidentally noted following the installation of a carp trap across the narrow neck of water leading out of a bay in Beaver Dam Lake, Dodge County, Wisconsin. With exclusion of carp from this bay, a dense stand of coontail (*Ceratophyllum demersum*) developed along with a minor stand of sago pondweed (*Potomageton pectinatus*). Nowhere else in the lake was there an equivalent stand of aquatic vegetation. In a repetition of observations in 1951 and 1952, it was found that carp were abundant and vegetation completely lacking. Essentially this same situation was repeated by excluding carp from a shallow bay in Lake Mason, Adams County. Here, again, the main basin of the lake had little vegetation, whereas it was abundant in the protected area.

These rather superficial observations were grounds to test more thoroughly the hypothesis that, given protection from carp, aquatic vegetation will prosper. Accordingly, in 1951, seven circular exclosures of chicken wire, each with a diameter of 16 feet, were constructed and installed in three lakes, Buffalo Lake, Lake Puckaway, and Lake Koshkonong, and again in 1952 in Lake Koshkonong. In addition, an entire bay of Lake Koshkonong was fenced off with chicken wire and observations made on changes in aquatic vegetation.

Circular exclosures were placed in the three locations in Lake Koshkonong and two localities in each of the other two lakes on July 5, 1951 (Table 1). The locations were chosen for having various conditions such as no vegetation, abundance of carp, mud bottom, sand bottom, exposure to and protection from wave action. Furthermore, chicken wire was used in the construction to minimize dissipation of wave action.

Inspection of these areas on August 7,

TABLE 1.—LOCATIONS AND DESCRIPTIONS OF CARP EXCLOSURES BUILT IN THREE WISCONSIN LAKES, JULY 5, 1951

	Lake	Location	Bottom type	Depth	Vegetation	State of rough fish problem
1.	Koshkonong	Revfik's Bay	Muck	3′	Sago pondweed	Acute
2.	Koshkonong	Thiebeau Pt.	Sand	2′	Floating leaf pondweed	Acute
3.	Koshkonong	Olson's Bay	Soft sand and muck	2′	Sago pondweed	Acute
4.	Buffalo	Outlet	Sand	3′	None	Acute
5.	Buffalo	Midlake Bay	Muck	18″	None	Acute
6.	Puckaway	Dredge bank	Muck	2′	Whitestem pondweed + 7 other species	Moderate
7.	Puckaway	Sandy Pt.	Sand	2′	Wild celery—scarce	Moderate

and September 11, of the same year yielded contrasting results. Those in Buffalo Lake had no vegetation before installation and none developed afterward. In Lake Puckaway there was no difference in the vegetation inside and outside the structures. At Lake Koshkonong the Olson's Bay structure, inside which there was no vegetation at the start, still had no vegetation inside, but there were beds outside. In the Revfik's Bay structure the vegetation inside the exclosure had disappeared while outside there were still scattered stems visible. Only in the Thiebeau Point structure was there a decided difference. Here there was more vegetation, namely floating-leaf pondweed (*P. americanus*), inside the structure than outside.

Although these results appear inconclusive at first glance, it was found that from three to nine inches of silt had been deposited inside the exclosures located in Buffalo Lake and Lake Koshkonong. Since all exclosures were located in reasonably protected locations where little wind action could be expected, activity of fish in roiling the bottom was held responsible for the deposition of silt. Possibly the deposit of 7 inches of silt smothered out plants in the Revfik's Bay location and prevented establishment elsewhere.

Under protection from fish, floating-leaf pondweed thrived at Thiebeau Point. To substantiate this, the same location was enclosed in 1952 on May 4, and another exclosure built beyond it in 34 inches of water where the bottom was soft mud. The in-shore exclosure over the sand bottom again enclosed floating-leaf pondweed and in addition scattered stems of sago. The outer exclosure contained only scattered stems of sago pondweed.

On July 3, both had dense stands of vegetation inside as well as outside. On August 15, most sago stems had wilted following fruiting and only a tangled mass of stems lay on the bottom. In the outer exclosure over soft bottom there appeared to be a slightly greater quantity of vegetation inside than in an equal area outside.

Although the sago disappeared, the floating-leaf pondweed prospered into September at the inner location. However, unlike the previous year there was a good stand of vegetation both inside and outside. When measurements of depth were taken, it was found that the depth was four inches less than surrounding areas at the inner location and eight inches less at the outer. The definite improvement in the growth of the vegetation can be associated with lessened carp activity, as indicated by the decreased catch per unit effort for carp fishermen, a decline from 18,862 pounds to 10,667 pounds. Even though there was sufficient fish activity to have caused deposition of silt similar to that the year before inside the exclosures plants were apparently thriving. Thus, it became apparent that silt was not necessarily a deterrent to growth of established plants as suggested by earlier observations.

As mentioned earlier, a chicken-wire fence was stretched across the entire mouth of Bingham's Bay, one of several comparable bays in Lake Koshkonong, a distance of approximately 1,600 feet. This fence was constructed on July 3, with a "V" leading lakeward to allow the escape of any fish which may have been entrapped in the 75 acres of water

enclosed by the fence. At time of construction, vegetation (mainly sago pondweed and a trace of coontail) was abundant both inside and outside the fence and the water was generally turbid.

The first inspection on July 9, showed early signs of improvement despite the fact that part of the fence had been disturbed. A Secchi disk reading of 26 inches was taken inside the fence while outside it was only 13 inches. Already, coontail had largely disappeared outside the fence whereas it was common inside.

In another inspection on August 15, turbidity was sufficient to blot out the Secchi disk at 15 inches in the lake. Inside the fence the bottom was clearly visible at three feet, there was no sign of turbidity, and there was a blanket of aquatic vegetation so dense it was impossible to run an outboard motor through it. Species observed were as follows: coontail, very abundant; floating-leaf pondweed, common; leafy pondweed (*P. foliosus*), common; flatstem pondweed (*P. zosteriformis*), common; and sago pondweed, common. In no other bay on the lake was there a stand of vegetation which approached that in Bingham's Bay in density or species composition.

The fence was removed on August 29, because high waters had reduced the effectiveness of the barrier. Vegetation was still very dense in the upper two-thirds of the bay and was comprised of essentially the same species along with some additions. A trace of wild rice (*Zizania aquatica*) was evident, naiad (*Najas flexilis*) common, and water weed (*Anacharis canadensis*) abundant. On all the inspections two small clones of yellow water lilies (*Nuphar*) were present.

In the lower third of the bay, where carp had access, vegetation was already greatly thinned and water muddied. It appeared as though carp were progressively browsing their way into the interior of the bed of vegetation.

Carp are apparently so closely associated with vegetation in their ecology in shallow waters that any major decrease in their numbers is quickly demonstrated by a recovery of vegetation. They appear not greatly unlike swine in their activities and succeeded in roiling water sufficiently to deposit as much as nine inches of silt on a protected area during a two-month summer period. Turbidity was increased sufficiently to decrease by one-half or more the distance light penetrates in the water.

Closing off an entire bay demonstrated the prolific nature of the vegetation and the destructive and grazing potential of carp. With protection, the vegetation developed into blanket proportions within only a part of one season while only barren waters lay outside the protected areas. The carp's approach to a new pasture of aquatics consisted of working the edge and opening the bed gradually. Should one be looking for signs of carp abundance, openings in the vegetation rather than the depletion of individual species of aquatic plants appear to be a good indicator. Fencing off a bay was successful enough to say that the practice has promise in protecting the vegetation of shallow bays for waterfowl.

The assistance of Mr. Llewellyn Peterson and his crew installing and maintaining carp exclosures is gratefully acknowledged.

LITERATURE CITED

ANDERSON, J. M. 1950. Vegetation changes

following fish removal. Jour. Wildl. Mgt. **14**: 206–209.

BLACK, J. D. 1946. Nature's own weed killer, the German carp. Wisconsin Conservation Bulletin, **11**(4): 3–7.

CAHN, A. R. 1929. The effect of carp on a small lake: Carp as dominant. Ecol. **10**: 271–274.

Accepted for publication May 13, 1953.

THE EFFECT OF CARP EXCLOSURES ON GROWTH OF SUBMERGED AQUATIC VEGETATION IN PYMATUNING LAKE, PENNSYLVANIA [1]

C. A. Tryon, Jr.

Pymatuning Laboratory of Field Biology, Department of Biological Sciences, University of Pittsburgh

Numerous workers have noted an association between a high population of carp and a low population of submerged, rooted aquatic vegetation. Ricker and Gottschalk, (1940), found that removing coarse fish resulted in an increase in extent and density of vegetation in Bass Lake, Indiana. The mechanism behind this association varies in kind and degree according to the ecological conditions presented by the body of water in which carp and vegetation occur. The bulk of experimental evidence that carp reduce vegetation has been derived from artificial ponds and other small bodies of water. Since this association exists in Pymatuning Lake to an unusual degree, it was decided to use fenced quadrats as a means of determining the effect produced by exclusion of carp during the growing season on vegetative growth.

Furthermore, quantitative studies of rooted submerged aquatic plants are scarce, as pointed out by Wilson (1939).

Pymatuning Lake is an impounded body of water on the border between Pennsylvania and Ohio. The upper portion known as Sanctuary Lake, lies entirely within a waterfowl sanctuary administered by the Pennsylvania Game Commission. It is separated from the rest of the lake by a dam that maintains it at a level at least two feet above that of the lower portion. The level is maintained throughout the year except when drawn down a foot in the summer by the Game Commission so that more shore area is exposed for vegetative growth. Sanctuary Lake contains about 2500 surface acres and has an average depth of six feet with a maximum depth of nine feet.

The temperature of the lake varies from 32°F. in the winter to 88°F. in the summer. During the winter the ice cover is not constant for more than a few weeks at a time. Light penetration during the growing season is relatively slight due to more or less constant blooms of blue-green algae, and to silt and detritus, stirred from bottom and shores by wave and animal activities. Light extinction as measured with a

[1] Contribution No. 5, Pymatuning Laboratory of Field Biology.

Weston photronic cell varies from 18 inches to four feet during the different seasons.

A description of the chemical conditions and plankton production in this lake during the summer months is given by Tryon and Jackson (1952). In general, oxygen is high, ranging from well above 100 per cent saturation in summer to 70–80 per cent in winter. Carbon dioxide is lacking in summer but reaches four to seven ppm. in winter. The lake would classify as medium-hard.

The bottom soils were originally composed of peat and muck from the swamp that existed in the area before the impoundment of the lake. These are now being overlaid by clay and sand washed from banks and shores. The pH of dried bottom samples ranged from 6 to 7.4.

The vegetation at present existing in Sanctuary Lake consists of much emergent growth and very little submerged vegetation. Of the submerged rooted aquatics *Potomogeton crispus, Potomogeton pectinatus* and *Anacharis canadensis* are the most common. Phytoplankton blooms (*Diplocystis sp.*) occur throughout summer causing organic weight records as high as 26.9 milligrams per liter. Fish and game workers state that submerged, rooted aquatics were abundant, especially *Anacharis*, during the first years of impoundment. Uhler and Aldrich in 1944 reported them as rare in this lake and they have apparently not increased since that time.

Carp are abundant and show good growth. They can be observed in shallows throughout summer during their spawning and feeding activities. The Pennsylvania Fish Commission removes approximately 4000 to 5000 carp annually from Sanctuary Lake by netting and seining. This causes no apparent reduction in their numbers.

Acknowledgments for assistance are due Frank Schwartz, Daniel Jackson, Gordon Ogden and Milan Drake. Howard Fox of the Pennsylvania Fish Commission was also most helpful. The Pennsylvania Game Commission permitted operation of quadrats within the Sanctuary.

METHODS

Quadrats were established at two stations during summers of 1950, 1951 and 1952. At each station two quadrats were established, one fenced with one-inch mesh galvanized wire netting and the second left unfenced. The netting extended a foot or more above water and was pressed into the bottom. No fish of any size were ever found within the enclosed quadrats. The fenced and unfenced quadrats were adjacent, sharing a common border, were square in shape and enclosed 1/100 acre. The fencing was erected each year during the last two weeks of June and was taken down during the last two weeks of September. Markers were left so that quadrats occupied the same places during succeeding years. The treatment of each quadrat was reversed each year. Thus a quadrat fenced in 1950 was unfenced in 1951 and fenced again in 1952. This would tend to prevent any compounding effect resulting from the fencing. During September whatever aquatic vegetation had grown in each quadrat was harvested by breaking or cutting the plants at the surface of the bottom. The plants from each quadrat were then bagged, air dried and weighed at the laboratory.

At Station 1 the water was two to three feet deep and the bottom was

peaty muck. The prevailing winds were on shore and the quadrats were placed 40 feet from shore. At Station 2 the water was one to two feet deep, the bottom was mud and sand and the prevailing wind was off shore. The quadrats were 15 feet from shore. During the period of fencing the quadrats were visited weekly.

RESULTS

The results of the investigation are given in Table 1. From screened quadrats the total weight of dried plants was 3.9 grams per square meter and from unscreened quadrats the total was 1.4 grams per square meter. The total production for Station 1 screened quadrats during the three year period was 1330 grams and for unscreened quadrats 655 grams. In Station 2 screened quadrats produced 598.3 grams and the unscreened produced 46.5 grams. The difference between enclosed and open quadrats was therefore of considerable degree and consistent from station to station and from year to year.

DISCUSSION

The use of screened exclosures always raises the question of how much the protection or other effects of fencing influence plant growth. In the case of aquatic quadrats, netting may provide protection from waves or currents and prevent dispersal or entrance of various materials. It was not felt that these had any appreciable effect in the present investigation due to the largeness of the mesh used. The screened quadrat at Station 2 in 1951 had a sufficiently heavy growth of *Potomogeton crispus* to give the surface a fairly solid appearance. This growth terminated abruptly at the netting. Between the quadrat and the shore vegetation was lacking even though this area was more protected from wave and current action than the area within the quadrat.

It is of course not possible to say with

TABLE 1.—WEIGHTS IN GRAMS OF AIR DRIED VEGETATIVE MATERIAL COLLECTED FROM 1/100-ACRE SCREENED AND UNSCREENED QUADRATS IN PYMATUNING LAKE

	1950		1951		1952	
	Closed	Open	Closed	Open	Closed	Open
STATION I						
Potomageton crispus	99.0	8.0	....	....	119.0	....
Potomageton pectinatus	....	....	2.0	1.0	3.0	....
Ceratophylum demersum	957.0	601.0	117.0	53.0	33.0	....
	1056.0	609.0	119.0	54.0	155.0	....
STATION II						
Potomageton crispus	....	....	526.0	27.0	36.5	19.5
Potomageton pectinatus	....	....	trace	trace	35.8	....
Ceratophylum demersum	....	....	....	....	....	....
			526.0	27.0	72.3	19.5

Total for closed quadrats—1918.3 Total for open quadrats—709.5

certainty that carp were responsible for lack of vegetation in open quadrats. Waterfowl or other animals could have been in part or even wholly responsible. However carp were abundant in the area and waterfowl were not during the annual period the quadrats were in operation. It is also not possible to say how the carp reduced the vegetation. Carp stomachs examined averaged roughly 65 per cent animal material and 35 per cent plant, the latter consisting mostly of algal material which often forms a scum on the surface of the water. This is close to the figures given for carp by Struthers (1929) although his specimens came from the New York State Canal and the plant material was of a different type. Turbidity was the same within the quadrats as without and no difference existed between open and closed quadrats. Therefore it would appear that if the carp are responsible for the lack of vegetation that it is due primarily to the mechanical effect of their rooting and splashing habits or to other unknown habits.

SUMMARY

1. In Pymatuning Lake, 1/100-acre paired quadrats, fenced and unfenced, were established. These quadrats were in operation during the vegetation growing seasons of 1950, 1951 and 1952.

2. The three-year average annual growth of submerged aquatics was 3.9 grams of air-dried vegetation per square meter in fenced quadrats and 1.4 grams per square meter in unfenced quadrats.

3. It appears likely that the rooting and splashing habits of carp are responsible for differences in production of submerged aquatics although other causes may be responsible.

4. While turbidity may be responsible for the general low production of submerged aquatics in the lake it did not appear to be responsible for the difference between fenced and unfenced quadrats.

LITERATURE CITED

RICKER, W. E. and J. GOTTSCHALK. 1940. An experiment in removing coarse fish from a lake. Trans. Amer. Fish. Soc. **70**: 382–390.

STRUTHERS, P. H. 1929. Carp control studies in the Erie Canal. A Biol. Surv. of the Erie-Niagara System. N. Y. Cons. Comm., Suppl. to 18th Ann. Report, 1928.

TRYON, C. A. JR. and D. F. JACKSON. 1952. Summer plankton productivity of Pymatuning Lake, Pennsylvania. Ecol., **33**: 342–350.

WILSON, L. R. 1939. Rooted plants and their relation to the limnology of freshwater lakes. *In* Problems of Lake Biology, Publ. No. 10, Amer. Assoc. Adv. Sci., Science Press.

Accepted for publication March 26, 1953.

DAILY PATTERNS OF PHEASANT HUNTING PRESSURE

Charles E. Friley, Jr.

Michigan Department of Conservation [1]

Many states or provinces have experimented at one time or another with different opening hours for hunting seasons. As an example, pheasant hunting regulations for 1949 in southern Michigan prohibited the hunting of pheasants before 10 a.m. This regulation was prompted by a desire to lengthen the pheasant season from 12 to 16 days without increasing total available hunting hours during a year of relatively low pheasant populations. Also considered was the desire to give farmers time to complete chores before the opening of hunting. Records of hunting at the Rose Lake Wildlife Experiment Station have shown the effect of the shorter hunting day on pheasant hunting pressure on a public hunting area.

The Rose Lake Station is located 12 miles northeast of Lansing, Michigan, in southeast Clinton County and southwest Shiawassee County. Its area was constant at about four square miles from 1948 through 1950, and about one-half square mile was added prior to the 1951 hunting season. During the small-game season, the station functions as a public hunting ground providing opportunity to hunt pheasants, cottontail rabbits, and fox squirrels. Ruhl (1947 Trans. No. Amer. Wildl. Conf. **12**: 496–503) describes the area and its broader functions.

All hunters are required to report to station headquarters before hunting to prepare a record card and to obtain a permit to hunt on one of six or seven management areas. At the conclusion of the hunt the hunter must return to headquarters, have his game examined by station biologists, provide additional information relative to his hunt, and return his permit. From these records data for the present paper have been obtained. Throughout the study the number of hunters on the station every half-hour form the basis for discussion.

One of the objectives of the Rose Lake Station has been to provide yardsticks and factual bases for making regulations relating to wildlife management of small game in southern Michigan. In keeping with this objective, a study was undertaken to determine the hunting pressure pattern on the station during pheasant seasons from 1948 through 1952. The study has shed some light on the hunting habits of pheasant hunters, on the influence of early and late daily opening hours on the total gun pressure, and on the effect of different days of the week on hunting pressure exerted on pheasant populations.

[1] Data are from investigations carried on under Pittman-Robertson Research W-40-R, Game Division, Michigan Department of Conservation. The writer is indebted to G. W. Bradt, under whose guidance the project was initiated; to C. T. Black for suggestions and assistance during preparation of the manuscript; and to my colleagues at the Rose Lake Wildlife Experiment Station who were equally instrumental in gathering the data on which it was based.

OPENING DAYS

The 1952 pheasant season opened at 10:00 a.m. on Monday. Heaviest pressure was reached at 11:30, when 140 hunters were on the station (Fig. 1).

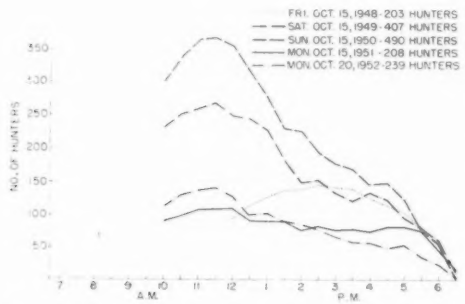
FRI. OCT. 15, 1948 - 203 HUNTERS
SAT. OCT. 15, 1949 - 407 HUNTERS
SUN. OCT. 15, 1950 - 490 HUNTERS
MON. OCT. 15, 1951 - 208 HUNTERS
MON. OCT. 20, 1952 - 239 HUNTERS
NO. OF HUNTERS
A.M.
P.M.

FIG. 1. Hunters in the field on the opening day of hunting season.

Thereafter pressure fell off steadily. The 1951 pheasant season also opened at 10:00 a.m. on Monday. Heaviest pressure that day, though lowest of any of the five opening days, was reached at 11:30, when 107 hunters were on the station. The peak was maintained until 12:00 noon after which pressure declined gradually for the rest of the day. The 1950 season opened at 10:00 a.m. on Sunday. Heaviest pressure was reached at 11:30, when 366 hunters were on the station. Pressure fell off steadily after 11:30 throughout the rest of the day. The 1949 season opened on Saturday, also at 10:00 a.m. Again the heaviest pressure occurred at 11:30, but at a lower level with 266 hunters on the station. And again pressure fell off steadily after 11:30 although a slight recovery was noted at 4:00 p.m. The 1948 season opened at noon on Friday. Peak pressure, 143 hunters at 2:30 p.m., was reached relatively later in the day and the pattern is more nearly that of a normal curve than those of the other four opening days.

The occurrence of opening day on Sunday (1950) produced the heaviest hunting pressure of any day in the five years studied. Peak pressure early in the day is characteristic of all 10:00 a.m. starting hours. A week-end opening day will invariably show heaviest daily pressure for the season, and Sunday shows a heavier pressure, consistently, than any other day of the week. It is not surprising that the combination of these two characteristics produces extremely high pressure.

The second day of the 1949 season fell on Sunday and hunting opened at 10:00 a.m. (Fig. 2). The pressure pattern

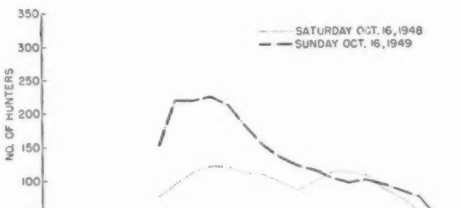

FIG. 2. Hunters in the field on the second day of hunting season (week-end day only).

is still that of an opening week-end day, a single peak of pressure early—221 hunters at 11:30 a.m.—but at a lower level. In 1948 the second day fell on Saturday with a 10:00 a.m. opening hour. The pressure pattern changed and shows two peaks of pressure instead of one but the heaviest pressure remains early with 119 hunters at 11:30 a.m.

The relationship between total pressure on each of five opening days (Fig. 1) and on corresponding days during the remainder of the season (Fig. 6 & 7) is constant. The same relationship holds

for the second day (Fig. 2). The second day in 1950, 1951, and 1952 fell on Monday, Tuesday, and Monday respectively. Since pressure and pattern were characteristic of other week days, they are considered with them.

SUNDAYS, SATURDAYS, AND WEEKDAYS

The remainder of the discussion excludes from consideration the five opening days and the two second days already treated, days of unusually heavy pressure at the beginning of the season.

Sundays with a 10:00 a.m. opening hour show a single peak of pressure occurring at 12 noon, but with a 7:00 a.m. opening two pressure peaks are apparent, the heavier occurring at 10:30 a.m. and the lighter at 4:00 p.m. (Fig. 3).

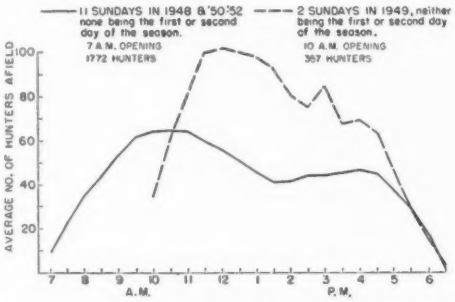
11 SUNDAYS IN 1948 & '50-'52, none being the first or second day of the season.
7 A.M. OPENING
1772 HUNTERS
2 SUNDAYS IN 1949, neither being the first or second day of the season.
10 A.M. OPENING
357 HUNTERS
AVERAGE NO. OF HUNTERS AFIELD
100
80
60
40
20
7 8 9 10 11 12 1 2 3 4 5 6
A.M.
P.M.

FIG. 3. Average number of hunters in the field on Sundays.

A longer hunting day allows adequate time for two groups of hunters to take the field, one in the morning and one in the afternoon, whereas in a shorter hunting day with a 10:00 a.m. opening hour, total hunting pressure is compressed into one much heavier peak period centering around noon.

On Saturdays (Fig. 4), two peaks of hunting pressure are apparent with both

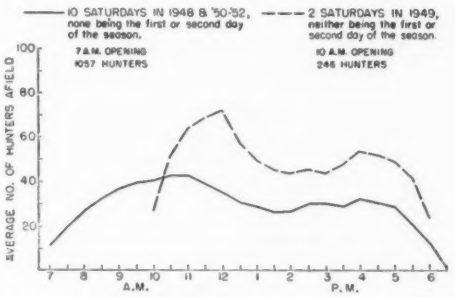
10 SATURDAYS IN 1948 & '50-'52, none being the first or second day of the season.
7 A.M. OPENING
1057 HUNTERS
2 SATURDAYS IN 1949, neither being the first or second day of the season.
10 A.M. OPENING
246 HUNTERS
AVERAGE NO. OF HUNTERS AFIELD
100
80
60
40
20
7 8 9 10 11 12 1 2 3 4 5 6
A.M.
P.M.

FIG. 4. Average number of hunters in the field on Saturdays.

10:00 a.m. and 7:00 a.m. opening hours. During the shorter hunting day pressure is concentrated within fewer hours with heavier pressure evident at any given time. The higher morning peak of the shorter day appears to be simply a compression of total pressure occurring in the mornings of those Saturdays opening at 7:00 a.m.

A definite trend toward heavier Saturday morning and lighter afternoon pressure appeared in 1951 and continued in 1952. This trend is probably due to the advent of football telecasting in 1951 over a local television station.

Week days, Monday through Friday, show two peaks of hunting pressure (Fig. 5). Days opening at 10:00 a.m. and

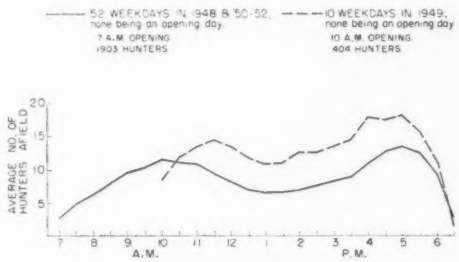

FIG. 5. Average number of hunters in the field on week days.

7:00 a.m. both show heavier pressure

peaks at 5:00 p.m. However, the morning peak is nearer the level of the afternoon peak in the case of the 7:00 a.m. opening hour than with the 10:00 a.m. opening hour, indicating again a compression of hunting effort into the shorter hunting day. It has been quite evident that the heavier pressure around 5:00 p.m. results from an influx of day-shift factory workers from Lansing.

OPENING HOURS

A comparison of pressure on different days with a 7:00 a.m. opening hour shows that Sunday is always heavier than Saturday, and both are heavier than week days (Fig. 6). Two peaks of

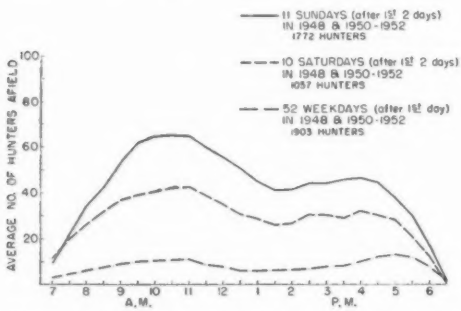

FIG. 6. Effect of day of week on pheasant season pressure pattern—7:00 a.m. opening hour.

pressure are evident on all days, with Saturday and Sunday high peaks coming in the morning while that of week-days is in the late afternoon.

With a 10:00 a.m. opening hour, Sunday pressure tends to be concentrated more in a single high morning peak (Fig. 7). Saturday and week day patterns retain the double peak characteristic, with the high peak of Saturday occurring during the morning. The high week-day peak is still late in the afternoon. The Saturday and Sunday patterns reflect strongly the enforced con-

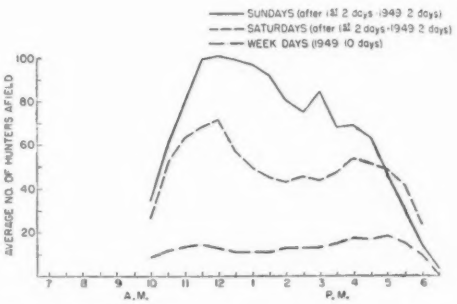

FIG. 7. Effect of day of week on pheasant season pressure pattern—10:00 a.m. opening hour.

centration of hunting effort imposed by cutting three morning hours off the hunting day. To a lesser degree this concentration carries into the week-day pattern. In spite of the number of hours available for hunting, a certain number of hunters will take the field. The effect of a shorter hunting day appears to be that significantly greater gun pressure is brought to bear on the game population in the early available hunting hours of any Saturday or Sunday than when a full day is available for hunting.

CONCLUSIONS

The net result of a shortened hunting day, particularly Saturdays and Sundays, is the high concentration of gun pressure within the first two hours. This concentration of pressure into two rather than five hours obviously increases hunter congestion and possibly further aggravates farmer-sportsman relationships.

Whether or not this shift of opening hour to later in the day is helpful in conserving game is beyond the scope of this paper. Preliminary analysis of other data showed no reduction in the total opening day kill. There is no evidence to show that hunting pressure was re-

duced by shortening the hunting day. On the contrary, there appears to have been an increase in the number of hunters in the field at any given time during the available hunting hours in 1949.

With the exception of the first two days of the season and Sundays, all days with a 10:00 a.m. opening hour show pressure peaks in both the morning and the afternoon with the noon meal hour apparently responsible for the low pressure between the peaks. With the 10:00 a.m. opening hour, the morning peak of pressure, at about 11:30, is attained in approximately half the time required to reach the morning peak on days with a 7:00 a.m. opening hour, and the former peak is greater.

For administrators at installations such as Rose Lake or controlled public hunting areas where heavy pressure is exerted on small game and where it is desirable to maintain close checks on both game kill and hunter pressure, the assignment of personnel involved in issuing permits and examining hunters and game bag at the end of the hunt can be more intelligently planned. On the state game areas, where random field checks of hunters are often made to determine pressure and kill, administrators will obtain maximum information by concentrating contact efforts at about the time maximum pressure begins to decline.

Accepted for publication May 7, 1953.

AN ANALYSIS OF WOODCOCK SINGING GROUND COUNTS, 1948-1952 [1]

E. L. Kozicky, T. A. Bancroft, and P. G. Homeyer [2]

Iowa Cooperative Wildlife Research Unit, Department Zoology and Entomology
Iowa State College, Ames, Iowa

In the spring of 1952, the cooperators utilizing the American woodcock (*Philohela minor*) singing ground count in northeastern United States and New Brunswick, Canada, approached the authors through Dr. J. W. Aldrich, to analyze the counts for any indication of population trend and for some measure of sample size necessary to predict population changes. Although the counts were not gathered in conformance with any standard statistical design, a statistical analysis was attempted.

Annual reports (Aldrich, *et al.*, 1952) were checked and the counts for the routes (44) that had been in operation since 1948 were extracted. With the aid

[1] Journal Paper No. J-2327 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 105. The Fish and Wildlife Service (U. S. Department of Interior), Iowa State College, Iowa State Conservation Commission, and the Wildlife Management Institute, cooperating.

[2] Leader, Iowa Cooperative Wildlife Research Unit; Director, Iowa State College Statistical Laboratory; and Professor, Iowa State College Statistical Laboratory, Iowa State College, Ames, Iowa, respectively.

of the cooperators the number of stops involved in making the singing ground counts on each route was determined (Table 1). The counts then were converted to the mean number of occupied singing grounds per stop per route in order to adjust for the various number of stops involved on different routes. For instance, the Calais, Maine, route, containing 100 stops, represented a composite of routes, compared to the Alexander, Maine, route with only seven stops.

The method employed in conducting the singing ground count has been outlined by Mendall and Aldous (1943). It was assumed that this procedure was followed by all observers; or if any modification of the procedure was initiated at individual routes by observers, these changes were strictly adhered to during the five-year period.

STATISTICAL ANALYSIS

The population is defined to be the aggregate of all possible routes in the Northeast Region with counts made in the manner used for this study. Data in this paper give no basis for determining the relationship between the mean number of occupied singing grounds per stop per route and the true number of woodcock in this region. It is, however, usually assumed that there is a high correlation between the number of occupied singing grounds per stop per route and the true number of woodcock.

Except where otherwise stated, the year effects were assumed to be fixed constants and the route effects were assumed to be random variables. The latter assumption was made even though the routes were not actually selected at random. Since the routes in this sample were restricted to areas that contained good woodcock cover, the variance among these routes is an underestimate of the variance among all possible routes. On the other hand this variance includes some variation attributed to geographic stratification which would make it an overestimate of the true sampling error. The influence of stratification in this case is probably smaller than that of the method for selecting routes.

An analysis of variance (Snedecor, 1946) of the mean number of occupied singing grounds per stop for the 44 routes for the five-year period is given in Table 2. Each mean was given equal weight even though the number of stops varied for the routes. Since the standard deviations of the routes for the individual years are linearily related to the yearly means (Table 3), an analysis of variance of the log transformed data was computed and is also given in Table 2.

A major question was whether a significant trend existed during the five-year period. The regression coefficient for a linear regression fitted to the yearly means for these particular 44 routes was negative and was significant at the five per cent probability level. A study of the linear regressions for the individual routes showed that the slopes differed significantly ($F = .0814/.0240$). No relationship could be found with the lack of slope conformance for individual routes and the geographical location or the relative length of the routes. Although a majority of the slopes were negative, some were positive and a few were practically zero. This heterogeneity is sufficiently large that if the routes are considered a sample from some population the average linear regression is not

TABLE 1.—AMERICAN WOODCOCK SINGING GROUND COUNTS FOR NORTHEASTERN UNITED STATES AND NEW BRUNSWICK, CANADA, 1948–1952

TABLE 1.—AMERICAN WOODCOCK SINGING GROUND COUNTS FOR NORTHEASTERN UNITED STATES AND NEW BRUNSWICK, CANADA, 1948–1952

Location of Route	YEAR 1948			1949			1950			1951			1952		
	No. of Occupied Singing Grounds	No. of Stops	Mean per Stop	No. of Occupied Singing Grounds	No. of Stops	Mean per Stop	No. of Occupied Singing Grounds	No. of Stops	Mean per Stop	No. of Occupied Singing Grounds	No. of Stops	Mean per Stop	No. of Occupied Singing Grounds	No. of Stops	Mean per Stop
Maine															
Calais	71	100	.710	63	100	.630	62	100	.620	63	100	.630	50	100	.500
Alexander	7	28	.250	9	28	.321	10	28	.357	5	28	.179	8	28	.286
Cooper	14	35	.400	17	35	.486	18	35	.514	11	35	.314	9	35	.257
Houlton	9	45	.200	7	45	.156	10	45	.222	9	45	.200	5	45	.111
Lamoine	5	10	.500	6	9	.667	8	10	.800	5	10	.500	6	10	.600
T4R10	8	17	.471	6	17	.353	9	17	.529	11	17	.647	9	17	.529
Orono	6	23	.261	1	22	.045	3	22	.136	4	22	.182	5	22	.227
Alton	9	22	.409	8	22	.364	7	22	.318	8	22	.364	9	22	.409
Gardiner	6	20	.300	8	20	.400	10	20	.500	12	20	.600	9	20	.450
New Hampshire															
Pittsburg	8	10	.800	12	13	.923	11	13	.846	12	13	.923	13	13	1.000
Vermont															
Highgate	7	10	.700	6	10	.600	9	10	.900	8	10	.800	7	10	.700
Moose River	22	17	1.294	21	17	1.235	24	19	1.263	18	19	.947	19	19	1.000
Waterford	11	13	.846	13	13	1.000	12	12	1.000	9	12	.750	8	12	.667
Marshfield	6	7	.857	5	9	.556	4	9	.444	4	9	.444	4	9	.444
Wheelerville	12	16	.750	17	16	1.062	13	18	.722	6	18	.333	9	18	.500
Shrewsbury	12	17	.706	16	18	.889	4	18	.222	12	18	.667	13	18	.722
Sherburne	3	7	.429	4	7	.571	2	7	.286	6	7	.857	6	7	.857
Ripton	16	18	.889	16	18	.889	14	19	.737	15	19	.789	10	19	.526
Halifax	6	8	.750	6	10	.600	5	10	.500	9	10	.900	8	10	.800
Mass.															
Newburyport	14	14	1.000	18	14	1.286	24	14	1.714	23	14	1.643	15	14	1.071
Conn.															
Litchfield	5	21	.238	8	21	.381	8	21	.381	5	21	.238	6	21	.286
E. Hartland	0	21	0	3	21	.143	1	21	.048	3	21	.143	1	21	.048
Glastonbury I	2	18	.111	4	18	.222	4	18	.222	4	18	.222	1	18	.056
Glastonbury II	4	10	.400	5	10	.500	5	10	.500	4	10	.400	2	10	.200
Branford I	5	11	.455	4	11	.364	2	11	.182	2	11	.182	2	11	.182
Branford II	3	11	.273	2	11	.182	1	11	.091	1	11	.091	1	11	.091
Guilford	7	21	.333	4	21	.190	6	22	.273	4	22	.182	8	22	.364
Eastford	4	21	.190	6	21	.286	5	21	.238	4	21	.190	4	21	.190
Portland I	3	13	.231	4	13	.308	1	13	.077	3	13	.231	7	13	.538
Portland II	7	19	.368	4	19	.211	6	19	.316	4	19	.211	10	19	.526
Shenepsit II	4	16	.250	6	17	.353	4	17	.235	2	17	.118	4	17	.235
Shenepsit III	1	19	.053	3	20	.150	1	20	.050	1	20	.050	2	20	.100
New York															
New Hudson	3	19	.158	8	21	.381	6	21	.286	4	21	.190	2	21	.095
Bethlehem	7	21	.333	6	23	.261	8	19	.421	10	19	.526	7	19	.368
Westerlo	6	27	.222	6	32	.188	9	28	.321	10	28	.357	14	28	.500
Guilderland-Knox	7	12	.583	5	12	.417	4	12	.333	9	12	.750	9	12	.750
Watertown-Adams	4	16	.250	3	16	.188	6	16	.375	6	16	.375	4	16	.250
Rodman	1	21	.048	2	21	.095	3	21	.143	3	21	.143	4	21	.190
Lysander	18	12	1.500	23	12	1.917	17	12	1.417	9	12	.750	10	12	.833
Wilmington	9	22	.409	9	22	.409	10	22	.455	14	22	.636	20	22	.909
New Brunswick															
Charter's Settlement	21	21	1.000	18	21	.857	13	21	.619	19	21	.905	13	21	.619
Kingsley Bridge	19	21	.905	13	21	.619	13	21	.619	15	21	.714	16	21	.762
Pa.															
Stone Valley	15	11	1.364	15	11	1.364	16	11	1.455	6	11	.545	4	11	.364
Barrens	15	12	1.250	16	12	1.333	16	12	1.333	2	12	.167	2	12	.167
Total	422	853	.495	436	870	.501	424	868	.488	394	868	.454	375	868	.432

TABLE 2.—ANALYSIS OF VARIANCE FOR THE WOODCOCK SINGING GROUND COUNTS ON 44 ROUTES, 1948–1952

Source of Variation	D.F.	Mean Square [1]	
		Original Data	Log Transformed Data
Among years	4	0.066980	.032697
Linear regression	1	0.213885	.....
Deviations from linear regression	3	0.018011	.....
Routes within years	215	0.133037	.151596
Routes	43	0.511598	.560185
Routes x years	172	0.038397	.049448
Routes x linear regression	43	0.081438	.....
Routes x deviations from linear regression	129	0.024050	.....
Total	219		

[1] Proper F-test for the hypothesis of interest depends on the model assumed.

significant (F = .2139/.0814). These results emphasize the importance of not placing too much credence in the counts of a few routes for regional trends in the species.

The variance among routes, standard deviation among routes, mean number of occupied singing grounds per stop per route and coefficient of variation for each year are given in Table 3. The standard deviations and means were linearily related; the correlation coefficient was 0.937. This explains the small variation among the coefficients of variation.

Table 4 contains three estimates of number of routes required each year to detect as significant at the five per cent probability level changes in the yearly mean of five, ten, fifteen, twenty and thirty per cent. All estimates of number of routes required are based on the appropriate variances of the log transformed data. Also, these variances were assumed to be the true variances.

The number of routes required assuming a new random draw of routes each year are listed in Column A. The variance used was that among route means

TABLE 3.—THE WOODCOCK SINGING GROUND COUNTS, FOR 44 ROUTES, 1948–1952

Year	Variance among Routes	Standard Deviation [1]	Mean No. of Occupied Singing Grounds per Stop	Coefficient of Variation (per cent)
1948	0.1415	0.3762	0.5328	70.6
1949	0.1707	0.4132	0.5534	74.7
1950	0.1643	0.4053	0.5232	77.5
1951	0.1074	0.3277	0.4769	68.7
1952	0.0813	0.2851	0.4609	61.9

[1] Correlation (r = 0.937) between the mean number of occupied singing groups per stop per route and the standard deviation is significant at the two per cent level.

TABLE 4.—NUMBER OF ROUTES REQUIRED TO ESTIMATE VARIOUS MEAN DIFFERENCES AS SIGNIFICANT AT THE 5 PER CENT PROBABILITY LEVEL

Mean difference expressed as percentage of 5-year mean	Number of routes required		
	A	B	C
5	2594	746	644
10	680	222	169
15	316	103	78
20	186	61	46
30	90	29	22

A. Between any two years assuming a new random draw of routes each year. Estimates based on variance of log means of routes within years.
B. Between any two years assuming that the same routes are visited each year.
C. Between consecutive years assuming that the same routes are visited each year.

within years. Sample sizes were computed using the formula

$$n \geq \frac{2t^2\sigma^2}{(\log x)^2}$$

For a five per cent change in the mean of the original data x is 1.05, for a ten per cent change x is 1.10, etc. Normal theory was used; i.e., infinite degrees of freedom were used for t. For an illustration, to measure a fifteen per cent change in the mean as significant at the five per cent level

$$n \geq \frac{2(1.96)^2\ (0.151596)}{(\log 1.15)^2}$$

$$\geq \frac{1.1648}{0.0036845}$$

$$\geq 316\ .$$

The number of routes required for significant yearly mean differences between any two years assuming that the same routes are included in the sample each year are listed in Column B. The intra-class correlation among years within routes is 0.708, which accounts for the large increase in efficiency for estimating yearly changes by using the same routes each year. The mean-square error, 0.151596, of the log transformed data for the interaction of routes with years was used as the estimate of the sampling variance. The data in Table 4 indicate that about three times as many routes would be required for a given precision if a new random sample were selected each year. The same formula as given above was used to estimate the sample sizes.

It is reasonable to suspect that the average correlation between consecutive years by routes is higher than that for years further apart. This correlation was 0.767 compared to 0.708 for the intraclass correlation. Therefore the average variance of the differences by routes for consecutive years was computed and found to be 0.075267, compared to 0.098896 for the variance of the differences between any two years. Using this variance the sample sizes in Column C were computed and are about 24 per cent less than those in Column B.

Under the stipulations in C the present 44 routes would detect a mean difference of 21 per cent at the five per cent probability level; under the stipulations in B, 24 per cent; and under the stipulations in A, 45 per cent.

DISCUSSION

As indicated under our definition of population in the section on statistical analysis, the biologist assumes that there is a correlation between the true number

of woodcock and the mean number of occupied singing grounds per stop per route. Assuming the validity of the correlation between mean number of singing ground counts per stop per route and woodcock population trends, methods must be found to reduce the bias that may be injected into these counts by some of the known variables that influence our present counts. Generally, the woodcock observers agree that such factors as high winds, temperature, rain, phase of the moon, variation between observers, time of day, duplication of counts, and stage of the breeding cycle are important variables. If we are to avoid bias in the data, such factors must be avoided or measured and our counts adjusted for deviations from conditions that reflect the most reliable estimate of the woodcock population present along any route. Our present analysis assumes that these known variables were held constant or acted in a random manner for the five-year period on the 44 routes.

The lack of adherence to the principle of randomization in the selection of routes should not be overlooked. Since inductive reasoning from the sample to the population is based on randomization of uncontrolled sources of variation, it was necessary to assume that the routes were a random sample from an aggregate of all possible routes containing woodcock in the Northeast Region. The routes, however, were selected mainly on the basis of the judgment and at the convenience of the individual cooperator. Such a selection of sample routes, although inexpensive and easy to conduct, has the possibility of injecting a constant component of error due to bias, which unlike random sampling error does not decrease on an average as the number of routes in the sample increased (Yates, 1949).

Information is needed on the life expectancy of singing grounds in attracting woodcock at a consistent annual level. Such data would not only enhance the evaluation of counts but would serve as a basis for providing an annual appraisal of new routes that should be added to the sample in order to continue the yearly estimate of population trends.

The distribution of woodcock during the census period needs to be investigated. If their distribution is correlated with vegetative cover types and/or geographical locations throughout the region, it may be feasible to increase the precision of the population estimate by further stratification of the sample routes. Also, a minimum of two routes should be selected at random from each stratum so that it would be possible to obtain unbiased estimates of the sampling error.

As Sheldon (1953) has shown that woodcock frequently change singing grounds and there is little assurance that the birds heard singing on any two nights from a singing ground are the same, there appears to be little value in retaining the present procedure of using the mean number of occupied singing grounds per stop per route on two or more evenings (Mendall and Aldous, 1943) as our basic sampling unit. Instead the possibility of utilizing the mean number of singing birds per stop per route for any one evening as the basic sampling unit could be analyzed. It may be possible for approximately the same expenditure of funds and time to increase the number of routes and

materially decrease the present sampling error.

The problem of obtaining a valid estimate of error with the present data is difficult, if not impossible. However, perhaps through further analysis of subsequent data, we can at least check the validity of our estimated error and over a period of time approach the true error involved in estimating population trends by woodcock singing ground counts.

In conclusion of this discussion, it may be well to point out that the biological and statistical problems of line sampling as a means of obtaining indices of wildlife population changes on an annual basis over large geographical areas needs further coordinated study by both the biologists and the statistician. For instance, at present we lack precise statistical methods for estimating the sample size necessary to predict nonlinear population trends with any specified precision. This particular analysis is merely an exploratory approach in the use of present sampling theory for studying one type of wildlife survey data.

SUMMARY

1. An attempt was made to analyze the woodcock singing ground counts for 44 routes in northeastern United States and New Brunswick, Canada, from 1948 through 1952 for any indications of a population trend of the species and to determine the importance of sample size in measuring population changes.

2. A study of the linear regressions for the individual routes showed that the slopes differed significantly. This heterogeneity of slopes was sufficiently large so that if the routes were considered a sample from some population, the average linear regression is not significant. These results emphasize the importance of not placing too much credence in the counts of a few routes for a regional trend in the species.

3. The standard deviations and means are linearly correlated, which explains the small variation among the coefficients of variation. Because of this relationship, all estimates of sample size were based on the log transformed data.

4. With the assumption that the estimated variances are true variances for the five-year period, an analysis of sample sizes necessary to reflect population mean differences showed that between consecutive years and with the same routes the present 44 routes would detect a mean difference of 21 per cent as significant as the five per cent probability level.

5. A discussion concerning the assumptions and variables involved is presented. It should be indicated that many of these assumptions are biological and relatively few are statistical; however, the latter, especially randomization, are essential in making inferences from the sample to the population.

ACKNOWLEDGMENTS

The authors wish to express their thanks for aid in securing the data on woodcock singing ground counts to Howard L. Mendall, Leader, Maine Cooperative Wildlife Research Unit, University of Maine, and to Prof. P. F. English, Department Zoology and Entomology, Pennsylvania State College. Acknowledgment is also made to the U. S. Fish and Wildlife Service, Washington, D. C., for a special grant toward defraying expenses for computing services.

LITERATURE CITED

ALDRICH, J. W., *et al.* 1952. Investigation of woodcock, snipe and rails in 1951. Special Scientific Report—Wildlife No. 14, U. S. Fish and Wildlife Service, Washington, D. C.

MENDALL, H. L. and C. M. ALDOUS. 1943. The ecology and management of the American woodcock. Maine Coop. Wildl. Res. Unit, Orono, Maine. 201 pp.

SHELDON, W. G. 1953. Woodcock studies in Massachusetts. Trans. N. A. Wildl. Conf. **18**: 369–377.

SNEDECOR, G. W. 1946. Statistical methods. Iowa State College Press, Ames, Iowa. 4th Ed.

YATES, F. 1949. Sampling methods for censuses and surveys. Hafner Publishing Co., N. Y.

Accepted for publication May 25, 1953.

AVAILABLE BROWSE FOLLOWING ASPEN LOGGING IN LOWER MICHIGAN [1]

Casey E. Westell, Jr.

Research Assistant, School of Natural Resources, University of Michigan [2]

INTRODUCTION

The aspen type, occupying two-fifths of the forested area in the Lower Peninsula of Michigan has been regarded until very recently as a weed species by foresters. Ten years ago few people could have envisioned conditions that would bring the 3,275,000 acres (Chase, 1947) of aspen stands in the Lower Peninsula of Michigan into economic prominence. Nevertheless, during the last five years, aspen has ceased to be a "weed-tree" and has become an important forest resource. Approximately two million acres of aspen are now, or eventually will be harvestable in this area. Other aspen stands totaling about one and one-quarter million acres are on sites too poor to permit growth to commercial size. The annual cut of "popple," as aspen is commonly known, has risen from virtually nothing a few years ago to 150,000 standard cords in 1951, representing an annual cut of some 15,000 acres. This raw product brought almost two million dollars in revenue to those supplying the mills in the Lower Peninsula in 1951. Within two or three years it is estimated that the yearly cut will reach 300,000 cords. Other Lake States are experiencing similar increases in use of aspen. Although mature stands of aspen are generally unattractive to wildlife, this is not true of recently cut-over areas. The large annual harvest of aspen will play an important role in wildlife management.

In the past it was the policy on both public and private lands to convert aspen stands to hardwoods or conifers of higher value. Consequently, research

[1] Paper #2, Phoenix Project #29, Aspen Study. Financed by contributions from wood-using industries and others.

[2] Appreciation is expressed to Professor S. A. Graham, who directed this investigation and offered suggestions in the preparation of the manuscript.

on aspen had been neglected and our basic knowledge of these trees in Lower Michigan was inadequate. In the spring of 1951 a study was initiated by the University of Michigan to determine basic facts about aspen and the effects of logging on Lower Peninsula aspen forests. The study is known as the University of Michigan Memorial Phoenix Project #29. One aspect of the project is concerned with the co-actions between aspen stands and white-tailed deer.

After two years of investigations, primarily based on intensive samplings of over 500 aspen stands in the northern half of the Lower Peninsula, certain facts clearly show that cut-over aspen stands are important to wildlife, especially to deer, and that deer influence aspen production. In the ten-county area around Manistee, 21 per cent of the aspen reproduction was browsed to some degree by deer. This browsing represents relatively light use and will, in most instances, have little influence on the future forest. However, in the twelve-county area surrounding Oscoda County, 42 per cent of the aspen reproduction was browsed—some cuttings being practically denuded of suckers. These results generally conform with differences known to exist in the deer populations of the two areas. Of course, the use of areas by deer is not uniform and the incidence of browsing on cut-over areas varies from 0 to 100 per cent.

Percentage figures for browsing do not tell the entire story, either in terms of available browse for deer or in terms of damage to reproduction. In our study of aspen reproduction on lands recently cut over an important question was: How much food is potentially available to the deer in the form of aspen suckers? An attempt to answer this is the aim of this paper.

In Michigan, two species of aspen occur, *Populus grandidentata* Michx., bigtooth aspen and *Populus tremuloides* Michx., trembling aspen, the former being the more important commercially in Lower Michigan. Bigtooth aspen of commercial size occurs in the general ratio of 3 : 1 in comparison with trembling aspen. The reverse of this situation prevails in more northerly parts of the Lake States. Most research on aspen has been concerned with trembling aspen in the Upper Peninsula of Michigan, Wisconsin, and Minnesota. The results are not applicable to our bigtooth stands. Although the two species are similar in many respects, the better commercial trembling aspen grows under cooler and more moist conditions than the bigtooth.

When aspen stands are harvested they reproduce by suckering of lateral roots. We have observed suckers as far as 66 feet from the parent stump, and other investigators have indicated that a 100-foot reproduction radius may be possible. Lateral roots, according to preliminary observation, undulate through the soil approaching within three or four inches of the surface at approximately six-foot intervals. Root suckers develop at these points provided the forest floor has been exposed to sunlight by cutting. The wandering lateral roots, from which the suckers arise, form an intricate and dense network. Because of this characteristic it is difficult to determine from which stump a sucker was derived. Under normal conditions a large number of suckers will shoot up on any cut-over area, varying from 1,000 to 35,000 suckers per acre, and averaging about 9,000.

During the first and second summers following cutting the aspen suckers have a prodigious rate of growth. Heights of six and eight feet are not uncommon at the end of the first summer's growth, but average heights are much less. Although aspen produces seeds prolifically, establishment of stands by seeding is no longer of significance in Lower Michigan.

METHODS

In order to evaluate the amount of browse available to deer on cut-over lands typical sucker stands were sampled by a series of mil-acre (6.6 feet square) plots. While basically simple, the technique involved was laborious and time-consuming. Consequently, these results are based on only ten mil-acre plots. In spite of their small number, we believe that the results are representative. In Manistee, Roscommon, and Oscoda Counties, satisfactory reproducing areas were located. Previous investigations provided data regarding species, stand composition, numbers of plants, soil, amount of animal activity, and other ecological information. Thus we had evidence that enabled us to locate, with confidence, a relatively small number of mil-acre samples in representative commercial aspen stands.

From one to five mil-acre plots were laid out in each cut-over area. These were located so that outside effects were minimized. Stakes were placed at corners of each plot. All suckers were cut at the soil line, sorted by height and species, and weighed. After this, the leaves and petioles were stripped from the plants and weighed. Then, each height group of stems minus leaves was cut at the 1/4-inch diameter point and the outer portions were weighed separately. Finally, the stems between 1/4 and 1/2 inch in diameter were cut and weighed. The bare stem represented the winter conditions and the twigs to 1/4 and 1/2 inch represented available browse. Summer browse was calculated as these twigs plus leaves and petioles. Weights were obtained with a five-pound limit Chatillon spring scale which could be read accurately to the nearest ounce.

The weight of associated browse species of trees and shrubs was obtained, but their combined weights were extremely small and have not been considered in this paper. From this it should not be inferred that the less numerous items of browse may not be important dietetically but rather that, normally, aspen sucker stands are so dense that successful secondary browse species are quantitatively unimportant in these areas.

RESULTS

The results have been tabulated according to height classes and all values have been reduced, for comparison and ease of application, to the base of 10,000 suckers per acre. Stems and leaves together represent available summer browse whereas twigs alone represent that available in winter. The diameter to which twigs are measured will bear a relation to the calculated amount of food available to deer. Under severe conditions of food scarcity the animals will literally chew off twigs 1/2 inch in diameter, but if food is abundant the 1/4 inch limit is more usual. The figures in Table 1, then, represent the amount of browse that could be used under the two population extremes. Observation indicates that the actual diameter limit

of aspen as browsed by deer lies somewhere between these values.

The results in Table 1 represent usual conditions in Lower Michigan. Amount of browse, as determined by actual weight from sample mil-acres has been reduced by 1/5 because we have found in sampling reproduction on 2,500 plots, throughout the northern half of the Lower Peninsula, that one out of five mil-acre plots have little or no reproduction on them. If conspicuous openings occur in a stand the browse value will be lower than indicated in the table. Although these estimates are for bigtooth aspen suckers, preliminary investigations show that the inclusion of up to 25 percent trembling aspen will not significantly alter these results. Pure stands of trembling aspen will yield ten to twenty per cent less browse.

Figure 1 indicates the ratios between edible and inedible portions of the aspen suckers between 3 and 5 1/2 feet in height for both summer and winter. These relationships are expressed in terms of green weight. Although water content varies somewhat with season, this had to be disregarded because it was essential that the same samples be used for both seasons. Examination of the diagrams reveals that the inedible portions increase with the height of the sucker until ultimately no twigs or leaves of the young tree can be reached by deer. Under normal conditions this point is attained in from three to six years.

APPLICATIONS AND RECOMMENDATIONS

It can readily be seen that cut-over aspen lands afford relatively large quantities of browse for a few years after cuting. An appreciation of that significance may be obtained by converting the quantity of available browse into deer-days of browse. Let us assume that seven pounds of browse per day are required per adult deer (Davenport, 1937). Converting the 1/4- and 1/2-inch values given in Table 1 we find that the deer-days of browse vary from 36 (250 pounds per acre) to 586 (4,100 pounds per acre). The average of all values given is 235 deer days of browse. Although it has not been demonstrated that deer can maintain themselves on a pure diet of aspen, we know it is a frequently-eaten food. We also know that in some areas where concentrations of deer occur, aspen is browsed to such a degree that 3 to 5 years after the cutting there is still no evidence of aspen reproduction except

TABLE 1.—POUNDS PER ACRE OF DEER BROWSE IN BIGTOOTH ASPEN SUCKER STANDS [1]

			Summer		Winter	
Average Sucker Hgt. in Ft.	Gross Wgt.	Wgt. of Leaves	Leaves & Stems 1/2 inch	Leaves & Stems 1/4 inch	Stems 1/2 inch	Stems 1/4 inch
3.0	700	400	700	650	300	250
3.5	1700	700	1600	1300	900	600
4.0	2700	900	2400	1600	1500	700
4.5	3800	1100	3100	2000	2000	900
5.0	4900	1400	3600	2400	2200	1000
5.5	6300	2300	4100	2600	1800	1300

[1] Original values have been adjusted to 10,000 suckers per acre.

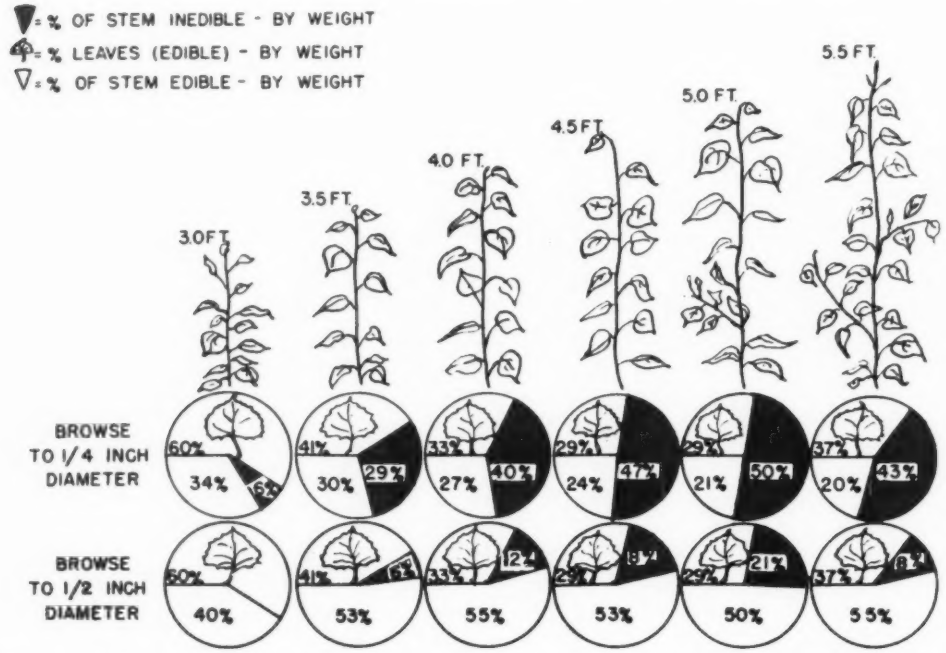

FIG. 1. Average weight ratios, by height classes, of edible and inedible portions of bigtooth aspen suckers.

inconspicuous browsed remnants of suckers.

Techniques and information such as this will enable the wildlife manager to make a more complete evaluation for wildlife of cut-over aspen lands. In a matter of a few minutes he can count the suckers on several mil-acre plots, determine the average height, and calculate from Table 1 approximately the amount of aspen browse available.

Knowing the approximate browse-producing potentialities of aspen lands, a wildlife manager can, by judicious cutting, provide food in or near deer yards. Forest cutting plans could thus be integrated with wildlife management plans to provide a continuous supply of this type of browse. It is important to emphasize, because of the rapid growth of aspen, that sucker stands provide available deer food for relatively short periods of time. Normally, after 3 to 6 years reproducing stands have either gained sufficient height so that succulent twigs and leaves are beyond the reach of deer or the suckers have been killed.

A question important both to wildlifer and forester if multiple use of the area is desirable is: What constitutes allowable browsing in aspen sucker stands, or for that matter, in any forest type? Naturally, an area stocked with an average of 9,000 suckers per acre will not carry to maturity all this reproduction. If 600 aspen trees per acre reach 4 inches d.b.h. a fully stocked timber stand will usually result. In very dense stands of young aspen proper growth and development slackens because of intense competition. Thinning produced

by deer and other agents has a releasing effect and is frequently beneficial. Therefore, it seems clear that a very large percentage of this reproduction may be used by deer without causing injury to the forest crop. As a rule of thumb, observations indicate that if in 3 to 5 years following aspen harvest, 1 to 3 aspen suckers per mil-acre have grown beyond the reach of the deer, stocking is still adequate for proper stand development. From this information one might justifiably postulate that generally from 1/2 to 3/4 of the available browse could be safely contributed to the deer herd. Although the allowable amount would vary from place to place we may very conservatively estimate, following the average aspen cutting, that from 100 to 150 deer days of food per acre would be available each year over a 3-year period. Such an estimate allows for a reasonable amount of aspen mortality from other causes and still insures an adequate stocking in the subsequent mature stand. Wisely used, aspen logging may help to alleviate the presently acute deer food problems, but without adequate harvest, deer populations may merely surge upward temporarily and produce an even more spectacular problem later.

SUMMARY

1. Aspen has ceased to be a "weed tree" in the Lake States and has become a valuable forest resource.

2. In Lower Michigan the aspen forest type occupies two-fifths of the forested area, and pulpwood logging is increasing rapidly.

3. Aspen-reproducing areas are attractive to wildlife, especially deer. Over 500 aspen stands and cut-over areas in the northern part of the Lower Peninsula of Michigan were sampled. In a ten-county area on the west side of the state 21 per cent of the aspen suckers were browsed. In a twelve-county area on the east side of the state, 42 per cent of the aspen suckers were browsed. These and other observations show that aspen is a frequent food of deer.

4. The number of aspen suckers on cut-over land varied from 1,000 to 35,000 per acre with an average of 9,000.

5. In order to evaluate the amount of browse available to deer on cut-over lands typical sucker stands were sampled by a series of mil-acre plots.

6. Plants of all species capable of providing browse were cut at the soil line, grouped according to height classes, then gross weights, leaf weights, and twig weights were obtained.

7. Effective deer browse was measured in two ways. Twigs were cut at the 1/4 inch and 1/2 inch diameter points and weighed. These two dimensions may represent the use by deer under normal and high population pressures.

8. Cut-over aspen lands afford relatively large quantities of browse for a few years after cutting. Conservatively, the average sucker stand will provide 100 to 150 deer days of browse per acre for a three-year period.

9. Knowing the approximate browse producing potentialities of aspen lands, a wildlife manager may often, by judicious cutting, provide food in or near deer yards.

LITERATURE CITED

CHASE, C. D. 1947. Aspen availability and supply. Lake States Aspen Report No. 2 Lake States For. Exp. Sta.

DAVENPORT, L. A. 1937. Find deer have marked food preferences. Mich. Conserv. 7: 4–6, 11.

Accepted for publication April 7, 1953.

REVIEWS

Bird Box Manual for Forest Protection. (Kontrollbuch für Vogelnistkästen in der Forstwirtschaft.) By Otto Henze. 1949. 2nd ed. Staatliche Vogelschutzwarte. Garmisch-Partenkirchen. 122 pp.

The implications of this book are not inconsiderable for the American reader, as it expresses a plight and a point of view which are now somewhat foreign to us, but both of which will be the inevitable result of many of our present forestry policies and practices if they are carried out without modification.

Reduction of intensive insect control during and since the war has accentuated the problem brought on in German forests by the policy of plantations—no dead trees, no weed trees, no wolf trees . . . a recipe, which having been carried on with extraordinary efficiency for generations has produced a disastrous imbalance in the forest. Henze has written a fascinating little book, exquisitely illustrated by Franz Murr, presenting a solution for part of the problem: bird houses!

For most of us, bird houses are largely a matter of taste;—some like them, some do not. Some use them for research on hole-nesting species. On the other hand we are not yet confronted by the problem of acres of merchantable timber or timber about to be merchantable in which a woodpecker might have to search over thousands of acres to find a tree in which to nest. Whole regions of German forests are essentially devoid of woodpeckers and almost lacking in chickadees, tits and other hole-nesters.

Nor are we confronted by the problem of maintaining the third generation of artificial forests—often on second rate sites, subject to insect damage—and the depletion which comes from generation after generation of spruce followed by spruce. German foresters have developed a degree of skill that is almost supernatural in growing good merchantable timber under artificial conditions, but human skills have not been able to keep abreast of man-made artificiality. The author states in no uncertain terms, "Man-made plantations are far more subject to climatic and pest damages than are natural woods or than is the forest primeval." German foresters are struggling to undo the mistakes of the past by breaking up monotypes and developing mixed stands.

Henze goes into meticulous detail covering: relationship between potential insect damage and suggested density of bird boxes, their placement, annual cleaning, numbering, repair and record keeping; also predator control, winter feeding and water for the birds. He suggests maintaining a sufficient density of bird boxes to keep down pest outbreaks before they can get started. The author does not claim that this is sure to work. He says that the effect that birds have on insect populations does not meet the eye, but "we do know that multitudes of insects are disappearing into the stomachs of birds." My main point in bringing this book to the attention of the American readers is not whether or not pests can be controlled by birds, but to show that artificiality has brought things to such a pass that bird boxes are seriously considered by the German Forest Service.—Frances Hamerstrom.

The Birds of Greenland. By Finn Salomonsen. Colour plates by Gitz-Johansen. Ejnar Munksgaard, Publisher, Copenhagen. 1950–51. 4°. Parts I–III, 608 pp., 52 full-page colour plates. Price Danish Kroner 180.

The first part of the Birds of Greenland was reviewed in the Jour. Wildl. Mgt., **16**: 101, 1952. Now all three parts are available and the standard work on Greenland birds completed. Much in this volume is of interest to North American ornithologists. Many Greenland birds winter on the North American continent, American stragglers reach Greenland and this vast island forms a stepping stone between the Old World and the New.

Finn Salomonsen, Curator of Birds of the Zoological Museum, University of Copenhagen, contributed the text which is fluently written yet concise, fully documented yet palatable, comprehensive in scope yet easily flowing. The text is bi-lingual, with columns in Danish and English, thus widening appreciably the usefulness of the volume.

Whereas the text should satisfy any ornithologist reading for pleasure or using the work

for reference, the colour plates have been the cause of varied opinion. Excellently produced in six-color off-set, each species portrayed gets a whole plate of its own. There is no doubt that these lavish plates do appeal to the more artistic-minded of bird students. The working ornithologist, interested in detail, does not get quite what he hopes for. The fact remains that this volume will be the standard work of Greenland ornithology for a long time to come, and it occurs to the reviewer that such standard work, with superb text, should have contained that kaleidoscope of bird portraits as produced by such eminent Danish bird artists as Johannes Larsen and Gerhard Heilman, and such fine bird photographs as produced by Alwin Pedersen, Arthur Christiansen and Chr. G. Vibe. Admittedly a higher unity (towards which only a few ornithologists would strive anyway) would have been disrupted if the Birds of Greenland had been made into a reference book with such varied, but unique pictorial material. It must be granted that author, artist and publisher have succeeded in creating an unusually well-produced and well-balanced volume. The fact-seeker will sigh when having to consider his purse and having to look somewhere else for plates showing subspecific details, photos of nests and eggs, habitats, etc. The artist-bird lover will say that this is it!

Part II covers gallinaceous birds, shorebirds, skuas, gulls and terns. The Greenland rock ptarmigan is treated in more detail than any other bird and the author has succeeded in giving an instructive account of this bird which taxonomically has given rise to some variety of opinion.

Of great interest is the inclusion of data from the recent banding of Greenland birds, supervised by Dr. Salomonsen.

Part III, which is the biggest of the three parts; discusses the remaining bird orders: auks, birds-of-prey, owls, and perching birds. It is with regret that one finds there are left only about 75 pairs of breeding white-tailed eagles in Greenland; no less than 37 per cent of the banded eagles were shot. The American subspecies of the peregrine falcon is a common breeding bird in Greenland; a bird banded at the American air base Blui West One was reported from Cuba.

There are very few passerines in Greenland, and it is interesting that three new species have become permanent breeding birds within the last few decades. One is the fieldfare whose appearance in eastern Greenland was storm-caused. Its crossing of the inland glacier and subsequent breeding and establishment in south-western Greenland, has already become a famous legend. The other two birds are the pipit and the white wagtail. The Greenland wheatear provides records of two transatlantic passages, from Greenland to England and to Portugal. The text contains a wealth of interesting details, many of which for the first time are presented to the English-speaking world. For example, we note that the raven lays her eggs when the temperature is as low as − 22°C. Details of nesting, food habits, migration, taxonomy and utilization are very comprehensive.

Of high value is the systematic list of the birds of Greenland, presented after the text proper. A total of 224 species of birds have been recorded from Greenland. To the American it is startling to see how many American birds have been recorded from Greenland, for example, no less than 17 species of warblers.

The bibliography, which in the author's own words: "pretends to be complete," cites everything which has been written about the birds of Greenland. It is a must to any student of arctic birds, and the occasional annotations aid the bird student in locating what he wants and saves him unnecessary hunting for less important papers.

A detailed index with references to species and subspecies, but not topics, concludes this gold mine of information on Greenland birds.

A large detailed map of Greenland has been especially prepared for this book.

In a time when the gust of cold war blows across continents and when hard economy cuts into all our ways of life, it is a pleasant experience to have been in the company of one who is rich in knowledge. It is with such a feeling that one closes this weighty volume.—KAJ WESTERSKOV.

Conservation of South Dakota's Natural Resources. By the Conservation Curriculum Workshop, Northern State Teachers College, Aberdeen, South Dakota. State Publishing Company. Pierre, South Dakota. vi + 168 pp. 1952.

This five-unit bulletin was prepared for use as part of South Dakota's State Course of Study in Science and Health for the sixth, seventh and eighth grades. The bulletin was prepared by a curriculum workshop group including both superintendents and elementary teachers, advised by specialists in biology, in conservation and in education.

The recommended grade placement is as follows: sixth grade, wildlife; seventh grade, plants and minerals; eighth grade, soil and water. Each unit presents a list of important concepts, develops appropriate factual material, includes suggested activities and references for pupils and teachers, and suggests useful visual aids. The suggested activities are keyed into the text of the unit at appropriate places. It is hoped that this technique will not result in teachers omitting the activities, since these are the heart of good conservation teaching. Perhaps it is unfortunate that the activities were not emphasized by interspersing them with the text material of the units.

The unit on wildlife deals in some detail with birds, mammals, fish, reptiles, amphibians and insects. In each group natural history, economic values, other relationships to man, and problems and methods of management as resources are developed. Throughout the bulletin a satisfying emphasis is placed upon the direct relationships between management of soils, water and plants and resulting benefits to wildlife.

Occasional errors in biology have been overlooked by the specialists who advised the workshop group. For example: it is implied on page 115 that Rocky Mountain sheep, Rocky Mountain goats, bison and many domestic animals shed their horns periodically.

It seems to this reviewer that the unit on wildlife is too academic in its treatment for sixth grade children. A wildlife unit should be full of experience with common animals. Out of these activities could develop a real understanding of wildlife needs, habits and ways of living.

In spite of the limitations mentioned, however, the present bulletin is a valuable addition to the growing list of state publications for use in teaching conservation in the schools. If, through workshops and other training sessions, the teachers can be widely acquainted with the bulletin and the best ways of using it in their classes, we can look for definite advances in the quality and amount of conservation instruction in the schools of South Dakota.—THEODORE E. ECKERT.

A Herd of Mule Deer. By Jean M. Linsdale and P. Quentin Tomich. University of California Press, Berkeley. 567 pages, 171 figures. 1953. $8.50.

This volume includes the field notes of thirteen years' gathering by Linsdale and his co-workers on the black-tailed deer of Hastings Reservation. Through this period their main concern has been the place of the deer in the ecological community and its adjustment to topography and climate.

It seems unfortunate that the vernacular name 'mule deer' rather than 'black-tailed deer' was used. Over most of North America the mule deer is one of the open-country races of the black-tailed deer species, whereas the term 'Columbian black-tail' is applied to the form treated in this volume. Though one may decry the general use of subspecific vernacular names, where animals are easily recognized by the general public, and where a racial vernacular is in current use, there is little to be gained by avoiding it.

The book throughout evinces a diligence in the encyclopaedic gathering of observations. The authors, rather than generalize from their many contacts with the species, have chosen to develop each point by documenting it in detail from their field notes and students of many aspects of animal biology will find here a wealth of information for interpretation and analysis.

The introductory section of 84 pages is devoted to descriptive material in which much attention is given to the antlers. The discovery that many bucks possess peculiarities of antler form that persist through the years is an important one. It has been successfully used to identify the successive sets shed by individual males and thus to verify seasonal distribution.

Antler beam diameters are compared for different point classes and confirm the findings of other authors that neither characteristic is satisfactory even as an approximation of age.

The second section of almost 200 pages is devoted broadly to different aspects of be-

haviour. In it the student of animal behaviour will find much of interest.

In a discussion of social organization the authors identify the milk group as the dominant one, with the maternal group (doe, fawns and yearlings) less stable. They did not notice the pairing of yearlings so commonly seen among the deer of Vancouver Island. Fraternal groups of bucks are another relatively stable form of association. Their feeding group seems hardly to merit separate designation as no evidence is offered that it is other than an aggregation at preferred feeding sites. One of the most rewarding contributions here is the detail of interaction of the deer and its predators based upon direct field observation of the species in contact. The bobcat is revealed as a predator only upon the young and then often under circumstances of hazard to itself. The aggressive behaviour of doe groups is regarded as an important contributory factor in fawn survival.

Chapter 5 is concerned with the relation of deer and other animals and includes a wealth of information on the parasites taken from deer on Hastings Reservation. Included are *Helictometra giardia*, *Taenia omissa*, and *Taenia serialis*, three cestodes not previously recorded from the black-tailed deer. In the notes on the behaviour of deer afflicted with larvae of *Cephenemyia* are observations of animals presumed to be infected. The authors unfortunately treat the observations as if the cause of the peculiar behaviour was established. The emergence of *Cephenemyia* in late September offers strong contrast with the situation further north in the range of the subspecies.

In the third section the authors present their observations of the influence of the habitat upon the behaviour of deer. Here the conclusion is reached that humidity was the most important climatic factor influencing behaviour, but the tabular data do not eliminate a diurnal, light-controlled rhythm in this role. It is most regrettable that the many graphs are not discussed in the text and the appropriate conclusions drawn.

There is a detailed treatment in Chapter 8 of plants eaten by deer though no attempt is made to indicate palatability or to quantify the utilization of different species. One significant contribution here is the discussion of the browse-line as it occurs on different species of plants. It is pointed out that browse lines occur at different heights above ground depending upon the relative palatability of the species. A graph is given (Fig. 155) illustrating the differences in 5 species of oaks. Its usefulness is impaired by the failure to include the units represented on either abscissa or ordinate. Table 15, however, gives the details in useful form.

In the final chapter, on population, some most significant observations are made. It is stated, for example, that where favourable forage becomes less, deer numbers decreased but that no instance had been detected of the population exceeding its food supply—an important situation that requires elucidation.

The photographs are excellent and generally well chosen. Errors in the text are few and in no way detract; the book is well produced with pleasing type faces and format.

My one major criticism is that the study is almost devoid of analysis; masses of meticulously taken observations are arranged under subject headings but are not developed into any organized theme, nor are they made to contribute to a unified situation that will advance our understanding of the ecology of deer.

The mere recording of observations does not constitute scientific research. The reviewer cannot escape the conviction that inductive research processes leading to hypotheses to be tested in the field would have been a more rewarding approach to the study under review. —I. McT. COWAN.

Social Behaviour in Animals. By N. Tinbergen. Methuen, London; and John Wiley, New York. xi and 150 pp. and 8 plates and 67 figures. 1953. $2.50.

This small book, the latest of Methuen's 'Monographs on Biological Subjects,' discusses the principal problems arising in the study of social behavior in animals. Present knowledge of the subject is summarized, and new theories are suggested to explain certain puzzling facts.

The author uses the term "social" in its broadest sense; to include cooperation between two individuals as well as cooperation among thousands.

His approach to the subject is ethological, following the pioneer work of Lorenz; and pri-

mary emphasis is placed on innate reactions. Particular attention, moreover, is devoted to fish and birds among the vertebrates.

The book is introduced by brief descriptions of social behavior in three much-studied species: the herring gull, the three-spined stickleback, and the grayling butterfly. This is followed by a detailed description of three main types of social "cooperation": mating behavior, family and group life, and fighting. The functions subserved by these activities are analysed with a wealth of examples. Subsequent chapters discuss causal factors producing such behavior, describe growth of social organizations in various animals, and consider certain evolutionary aspects of social organizations.

Photographs and numerous black-and-white drawings increase the value of both descriptions and discussion.

Although most cited examples refer to European animals and do not include species of most importance in wildlife management, this book should certainly be read by any biologist interested in any aspect of animal behavior. It is probably the best introduction to the subject yet published.—M. MOYNIHAN.

Round River / From the journals of Aldo Leopold. Edited by Luna B. Leopold. Illustrated by Charles W. Schwartz. Oxford University Press, New York. xiii+173 pp. $3.00. 1953.

This is a series of unpublished essays and journal excerpts compiled and arranged into three parts. The first, labeled "A Man's Leisure Time," comprises only one essay of the same title. It is concerned with the benefits one can derive from a constructive hobby. The second, called "Country" is a series of journal excerpts on field trips from Canada to Mexico, plus appropriately spaced essays in the title theme. This section is the body of the book and covers some 140 pages; the third and last section is entitled "Round River" and contains three philosophical essays.

The reader should not expect this book to be of similar quality or superior to *Sand County Almanac* (Leopold, 1949, Oxford). If he does, he is in for a disappointment, albeit of short duration. *Sand County Almanac* is the essence distilled from Aldo Leopold's lifetime of experience in the field as a sportsman and professional conservationist. The substance from which this essence was drawn has not been discarded, but in *Round River* is refined as the delightful by-product of a rich outdoor life recorded on the spot or viewed in retrospect. It must be remembered that the author did not and perhaps would not have published these writings, and as a consequence they are lacking in the fine ecological and literary polish normally expected of his finished work. Indeed, *Sand County Almanac* is the sequel to *Round River*, despite the fact that they were published in reverse order.

The text shows that the author suffered from the human frailties that plague most of us and that his growth as a conservationist was slow, forceful, and lasting. For example, some of the excerpts from his field journals reveal that at one time he trapped and shot lynx, tried to trap coyotes, shot a bobcat and a fox, and that his party killed avocets. To the creased-pants woodsman this may be shocking, but not so to those who realize that this "blood and guts" stage in the author's life was a vital factor in the intellectual growth of a great conservationist. In 1922, he shot a duck hawk on the Delta of the Colorado and as a matter of fact, records this in his journal. In the essay "Conservation," which was written in 1938, he expresses the antithesis of his 1922 experience when he says "The basic question is whether a hawkless, owl-less countryside is a livable countryside for Americans with eyes to see and ears to hear. Hawks and owls are a part of the land mechanism." Here is evidence of this intellectual growth. Further, these writings show that his convictions were wrought from experience, not copied; nor were they piously assumed to be innate. The individual trips afield so pleasingly portrayed must be considered as to time and place in order to understand fully the subtle story of Aldo Leopold's evolution as a conservation thinker and teacher. In fact, that evolution is the story to be read between the lines of this book.

Round River will appeal particularly to the "hunter" and this does not mean only the powder-burning kind, but all those who thrill to a hunt. As the author puts it, "The final test of the hunter is whether he is keen to go hunting in a vacant lot." In these essays also

is the why and wherefore of this man's attraction for kindred souls, the number of which has not diminished since his death.

The title essay, "Round River," is somewhat involved in that it tries to cover too much ground. Its salient idea is the concept of food chains and the interdependence of soil, plants and animals. Although the prose is pleasing to read, moving, and informative, the main theme is frequently lost. Even so, it is better than most dissertations on that subject.

The last essay, "Goose Music," is a philosophical appraisal of hunting (and fishing) as a social asset to the nation. Here also is a Leopoldian evaluation of the chase, its objects, and the hunter. So fervent is his plea for the outdoor aesthetic which to him is represented in "goose music," that to ignore or fail to understand this music is almost sacrilegious. In part, this climax essay may be rationalization, but I cannot point out where because I am blinded by the same light.

The final paragraph in the book starts with the statement, "I have congenital hunting fever and three sons." That which follows summarizes all that is said so eloquently throughout the book. Personally, it will help me explain to my boys why and how hunting fever will make for a richer life. To each reader of this book there will also come the realization that his inner personal responses to experience in the field are most expressively phrased in the words of the author.

Often in the emotional reaction to a posthumous publication of this kind we lose sight of the fact that much hard work has gone into the compiling and editing of the manuscript. Luna B. Leopold has done an exceptionally fine job of choosing and arranging the pieces that give us further insight into the life of his father. His brief but dignified preface indicates that the Leopold flare for lucid and appealing expression may also be congenital.

Charles W. Schwartz's black-and-white illustrations capture the changing moods of the book. Even in the anatomically inaccurate ruffed grouse (p. 74) his execution is superb.

Many times since his death, Aldo Leopold's writings have been likened to those of Thoreau. This comparison would doubtless have made Thoreau very happy.—ROBERT A. MCCABE.

Methods and Principles of Systematic Zoology. By Ernst Mayr, E. Gorton Linsley, Robert L. Usinger. McGraw-Hill, New York and London. x+328 pp., 45 Figs., 15 Tables. $6.00. 1953.

At long last here is a textbook that is going to become just as necessary for ecologists and zoologists concerned with taxonomic problems as Mayr's "Systematics and the Origin of Species" (1942) or Dobzhansky's, "Genetics and the Origin of Species" (1951). Ferris' "Principles of Systematic Entomology" (1928) provided a tool for budding entomologists and likewise had widespread use by taxonomists in allied fields. The present text, however, is much more broadly conceived, covering Taxonomic Categories and Concepts (Part I), Taxonomic Procedure (Part II), and Zoological Nomenclature (Part III). Where Mayr, Dobzhansky, and Ferris are less concerned with the broader outlines of taxonomic problems and more with their own disciplines in relation to speciation problems, the Mayr, Linsley, Usinger text is broad in scope, beautifully written in the main, and in most ways represents a complete and detailed formulation of taxonomic history, principles and procedures. It could have included much more on such items as quantitative methods, the concept of ecological species or races and evolution, but evidently a desire by the authors to keep the book to a reasonable size and to deal in facts rather than philosophy forced omission of these broader problems. The discussion of each item is brief and to the point and usually well supported by citation of numerous examples. The text contains evidence of much careful, thoughtful editing chapter by chapter and certain unevenness in the text doubtless resulted from the triumvirate nature of the authorship.

Part I includes three chapters: 1. Taxonomy, its History and Functions; 2. The Species and the Infraspecific Categories; 3. Classification and the Higher Categories. Part II includes six chapters bearing the following titles: 4. Collecting and Collections; 5. Identification and Taxonomic Discrimination; 6. Taxonomic Characters; 7. Quantitative Methods and Analysis; 8. Presentation of Findings; 9. Preparation of Taxonomic Papers. Part III covers eight chapters as follows: 10. Historical

and Philosophical Basis of Nomenclature; 11. The Principle of Priority; 12. The Type Method and Its Significance; 13. Specific and Infraspecific Names; 14. Generic Names; 15. Family Names; 16. Names of Orders, Classes and Phyla; 17. Ethics in Taxonomy.

There is a separate bibliography for each chapter at the end of the book. To this reviewer at least, this makes for cumbersome general use unless one follows the references directly from the text. One composite bibliography for the entire book would have saved duplication of references and increased its general usefulness.

A glossary of taxonomic terms used is one of the most useful features. These, arranged in alphabetic order, are brief definitions of most terms commonly used in taxonomic work. This is quite complete with omission of only a few terms such as biotope and biocoenosis, though both biota and biotype are listed.

A feature that especially appeals to me because of its great value for beginning students in taxonomy is a "Discrimination Grid" presented on page 79 in Chapter 5. In this three-column table, three sets of questions are listed to aid the student in determining whether two given collections or samples are intrapopulation variants, subspecies or species. These are reproductive isolation, morphological differences and geographical relationships. The grid is suggestive only and its clear-cut divisions would not apply to some animal groups such as the Genus *Salmo* since the factors of reproductive isolation and geographic distribution are impossible to define in many instances. Nonetheless, this and many other extremely useful features make it certain that this book is likely to become a standard in its field for many years and its influence will be profound. —PAUL R. NEEDHAM.

RECENT PUBLICATIONS

The Mammals of Minnesota. By Harvey L. Gunderson and James R. Beer. University of Minnesota Press, Minneapolis, xii+190 pp. $3.50 cloth, $2.00 paper. 1953.

This catalog of Minnesota's recent mammals is primarily for students in that state, but the mammalogist interested in precise details of distribution will also find it of value, for each species is represented by a full-page map showing its Minnesota distribution by counties, as well as a small generalized inset map of its North American distribution. Each species account, in less than a page of text, presents dental formula, weights and measurements, and selected references, in addition to the general account, which is primarily on distribution in the state. Binomials only are used except in *Peromyscus*. The keys to species are based on both skeletal and external characters.

Up to date and authoritative, it contains a number of items of general interest, among them the following: the last state caribou record was 1943; moose have been found recently in Pine County, only 100 miles from Minneapolis; of several mule deer taken in recent years, one is in the county where St. Paul is located; the Minnesota elk herd has declined to "about thirty-nine"; there are several recent cougar records, unverified by specimens but convincing nevertheless; the timber wolf is still present but limited now to the "wilder portion of the north woods"; the fisher is still found occasionally in northern Minnesota, but there have been no records of the marten for many years.—GUSTAV A. SWANSON.

A Guide to Bird Finding West of the Mississippi. By Olin Sewall Pettingill, Jr., with illustrations by George M. Sutton. New York, Oxford University Press. 709 pp. 1953. $6.00.

This is a companion volume to Pettingill's popular "Guide to Bird Finding East of the Mississippi" (1951). Like that volume, it will prove most useful and acceptable to travelling bird-finders. Prepared with the cooperation of over 300 naturalists (listed at the end of each chapter) it is divided into 22 chapters, one for each state included. For each state is given a brief summary of physiographic regions and biological communities with lists of the birds to be found in each and with specific directions for reaching the more interesting ornithological spots. Reference is made, likewise, to the

winter-bird life and the migration periods for each area.

One of the most useful parts of the book is the index which not only gives the page reference to all localities mentioned in the text but also to all the birds so that if one is interested in a particular species, he can quickly find where he can expect to see it. For example, there are 34 references given for the blue grouse, 16 for the sharp-tailed grouse, and 9 for the prairie chicken.

At the end of the book is a list of suggested reference material including recent regional publications that are for the most part still available.—ARTHUR A. ALLEN.

Studies of the Food Habits and the Habitat of Moose in Ontario. By Randolph L. Peterson. Contributions of the Royal Ontario Museum of Zoology and Palaeontology, No. 36. 49 pp. Toronto, 1953.

Winter browse studies on Isle St. Ignace are compared with those of Aldous and Krefting on Isle Royale. Stomach and dropping analyses support the conclusion that balsam fir is the most important Ontario moose food. Factors influencing balsam fir in moose habitat are discussed.

Housing for Wood Ducks. By Frank C. Bellrose. Illinois Natural History Survey Circular 45. 47 pp. Urbana, 1953.

An excellent, profusely illustrated report of Illinois' outstanding contributions to wood duck research and management. Many types of boxes are described, with recommendations for location and spacing for best results.

Songbirds in Your Garden. By John K. Terres. Thomas Y. Crowell Company, New York. 274 pp., illus. 1953. $3.95.

The last few years have seen several books and numerous articles on attracting birds. This one, by the Managing Editor of Audubon Magazine, is certainly one of the best and most complete this reviewer has seen on the subject. It covers thoroughly all usual topics found in similar books, and has in addition a wealth of suggestions on unusual problems (and some common ones) that have not been collected in one place before.

For example, anyone confronted with the problem of force-feeding a wild bird will appreciate the directions on how to hold the bird, to open its mouth and to insert the food. A chapter on special problems takes up, for example, what to do about squirrels and wasps; when to clean birdhouses so as not to destroy the insect parasites of blow fly larvae, and how to build a brush pile.

Other points which have sometimes been omitted by other writers include the necessity of ventilation in bird houses, the need for grit and eggshells, and for water in winter.

The appendix contains 19 useful lists including a list of birds and their favorite plants; a list of food plants for different sections of the country, rated according to their preference by birds; a very good list of foods to use at stations and birds that will eat each; plants that will attract hummingbirds; flowers whose seeds are attractive to birds; and one particularly useful and rarely seen compilation of nesting records for certain birds of city and country gardens, which gives, when known, the average number of eggs per set, incubation periods, days young are in nest and number of broods each year. Many will appreciate the index, often lacking in a book of this sort.

The book is rich with personal experiences of the author and with anecdotes he has gathered, which give a warm friendly style to his writing, appealing to all ages.—SALLY F. HOYT.

British Trust for Ornithology: Nineteenth Annual Report, 1952. 65 pp. Oxford, England. 2s, 6d.

Contains a short history of The Edward Grey Institute of Field Ornithology by David Lack, and of the development of The British Trust for Ornithology by James Fisher; also brief outlines of investigations being conducted by these organizations.

Upper Saugeen Valley Conservation Report. 1953. Dept. of Planning and Development, Toronto, Ontario. 170 pp. illus.

An attractive summary of surveys and recommendations made under a recent "Valley Conservation Authority" in Ontario. Another fine example of conservation by cooperating municipalities in small watersheds.

BRIEFER ARTICLES

A FIELD OBSERVATION METHOD OF AGING BROODS OF WOOD DUCKS

Robert E. Dreis
Box 54, Black River Falls, Wisconsin

This paper attempts to set forth an aging method for broods of wood ducks (*Aix sponsa*) based on comparative size of adult hen and duckling and on duckling habits, which appear to be peculiar to given age classes.

In 1951 the author undertook an investigation of wood duck production from nesting boxes and natural cavities (Dreis and Hendrickson, 1952). The study was conducted on the Lake Odessa Area, Louisa County, Iowa. This area was formerly a bayou of the Mississippi River and is now an abandoned drainage district. Within it are contained 5,800 acres, of which approximately 2,500 acres are open water, 2,600 acres are swamp and timbered bottomland and 700 acres are tilled and abandoned farm land (Schreiner and Hendrickson, 1951). Fifteen lakes, which are connected by ditches, and innumerable ponds make the area an ideal habitat for wood duck.

The investigation was carried on continuously from April 1 until August 20, 1951. In the course of observing broods of known ages (from nest boxes and natural cavities) a method was developed for determining age by size and habit.

Broods were located by cruising the entire area in a motorboat, by keeping watch from blinds and by trips on foot into the bottomlands and along ditchbanks. Practically all broods were found early in the morning—from the first indication of daylight until approximately 8:00 a.m. After this hour the hen usually led her brood into dense cover where they remained until dusk. The location of each brood was marked on a map. A given family unit was thus not too difficult to find again at regular intervals as broods did not wander from pond to pond until ducklings were capable of flight. The habits of eight separate broods were observed in this manner.

The adult hen would often feign injury and swim with an apparently broken wing in a direction directly opposite to that in which her

TABLE 1.—AGING CHARACTERISTICS FOR BROODS OF WOOD DUCKS

Age Class	Characteristics of Ducklings
Under 1 Week	1. 1/8 as large as the adult hen*
	2. In compact group at hen's side
	3. Run or swim into cover as a group when pursued
	4. Hidden in dense cover on land most of the day
2 to 3 Weeks	1. 1/4 as large as the adult hen*
	2. In close proximity of the adult hen
	3. Scatter somewhat and swim into cover when pursued
	4. Dive and swim under water for short distances
4 to 5 Weeks	1. 1/2 as large as the adult hen*
	2. Stray short distances from hen while feeding (15 feet)
	3. Dive and come out on shore when pursued
	4. Rest on logs and stumps in or near water
6 to 7 Weeks	1. 3/4 as large as the adult hen*
	2. Scatter up to 50 feet while feeding
	3. Fly short distance when pursued; dive and come out on land after alighting on water
	4. Rest on stumps 2 to 4 feet above water
8 Weeks +	1. Same size as the adult hen
	2. Scatter widely when feeding (50 feet +)
	3. Fly from sight when pursued
	4. Fly about as a family unit and frequently alight in trees

* Approximate size.

brood was hidden. Such action by a wood duck hen is a certain indication that a brood is hidden nearby. Saunders (1937) recorded a similar action where a hen successfully diverted the attention of a red-shouldered hawk (*Buteo l. lineatus*) from her brood.

Table 1 lists the characteristics for broods of given age classes. The characteristic most readily noted by most observers will be comparative size of attendant hen and her ducklings. This is approximate, and not by weight or body measurement. Habit characteristics are listed in order of reliability.

It is believed that this method has value because it is not necessary to have a duckling in the hand to determine its approximate age. It should be pointed out that this method was developed on wood ducks and may not apply to any other species of duck.

The author wishes to express his gratitude to Keith Schreiner who first suggested to him that an age-habit method could be worked out, and to George O. Hendrickson, under whose guidance the author made this wood duck investigation in 1951.

LITERATURE CITED

DREIS, R. E. and G. O. HENDRICKSON. 1952. Wood duck production from nest-boxes and natural cavities on the Lake Odessa area, Iowa, in 1951. Iowa Bird Life, **22**: 18–22.

SAUNDERS, A. A. 1937. Injury-feigning by a wood duck. Auk, **54**: 202.

SCHREINER, K. M. and G. O. HENDRICKSON. 1951. Wood duck production aided by nesting boxes, Lake Odessa, Iowa, in 1950. Iowa Bird Life, **21**: 6–10.

Accepted for publication June 3, 1953.

AN AUTOMATIC LIVE-TRAP FOR RAPTORIAL BIRDS

Harrison B. Tordoff

Museum of Natural History, University of Kansas, Lawrence, Kansas

Although many types of traps for adult raptorial birds have been designed, these birds remain among the most difficult to trap. This paper describes an automatic trap for raptors that is reasonably simple in design and construction and that has the advantages of high portability and rapid setting. The trap described below is basically a bow-net trap made automatic in operation.

I am grateful to George P. Young, Maurice F. Baker, and William M. Lynn for helping me in various ways to develop this trap.

DESCRIPTION

Dimensions given below are for traps designed for small hawks, small owls, and shrikes. I have successfully used traps of this size for sparrow hawks (*Falco sparverius*), screech owls (*Otus asio*), and loggerhead shrikes (*Lanius ludovicianus*). Larger traps of the same type can be readily constructed for larger raptors.

The platform of the trap is made of 1″ x 2″ or 1″ x 1″ welded wire fencing material stiffened around the margin by 1/4″ iron rod. The platform measures 32″ by 23″. In earlier models, I used 1/4″ Masonite for the platform. This material had several disadvantages as compared to the wire platform. Masonite is heavy, it deteriorates when wet, and, most important, it is difficult to camouflage. The high visibility of the Masonite base considerably increased trap-shyness in sparrow hawks.

Mounted on the platform is a hoop of no. 9 gauge or larger wire which is powered at both ends by springs from standard break-back rat traps. When set, the hoop is held open at its center by a latch. This latch is sprung by a rat trap mounted at the opposite end of the platform. The hoop travels through an arc of 180° in springing. Thus the trap is essentially flat both when set and when sprung. A net of good quality cheese cloth or fine-mesh nylon is attached to the hoop and platform. The trap is baited with a live mouse or sparrow.

DETAILS OF CONSTRUCTION

Platform.—The 1/4″ iron rod is bent into a rectangular frame 32″ by 23″. The ends of

the rod are overlapped several inches and fastened together by two rivets. Satisfactory rivets can be made from nails. The welded wire mesh should be cut approximately two inches larger in each dimension than the frame. The platform is then completed simply by clinching the edges of the mesh around the frame. The resulting platform is light and rigid (Fig. 1,C).

Wire mesh larger than indicated should not be used in a trap designed for shrikes or sparrow hawks because of the possibility of a trapped bird escaping through the base if the trap is placed on uneven ground.

Hoop.—Galvanized iron wire of no smaller than no. 9 gauge is used for the hoop. The wire for the hoop should be cut at least 15 inches longer than the arc of the finished hoop to allow for fitting the ends of the hoop to the propulsion springs, the latter taken from a standard rat trap. Care should be taken to use springs from a type of trap which has the two

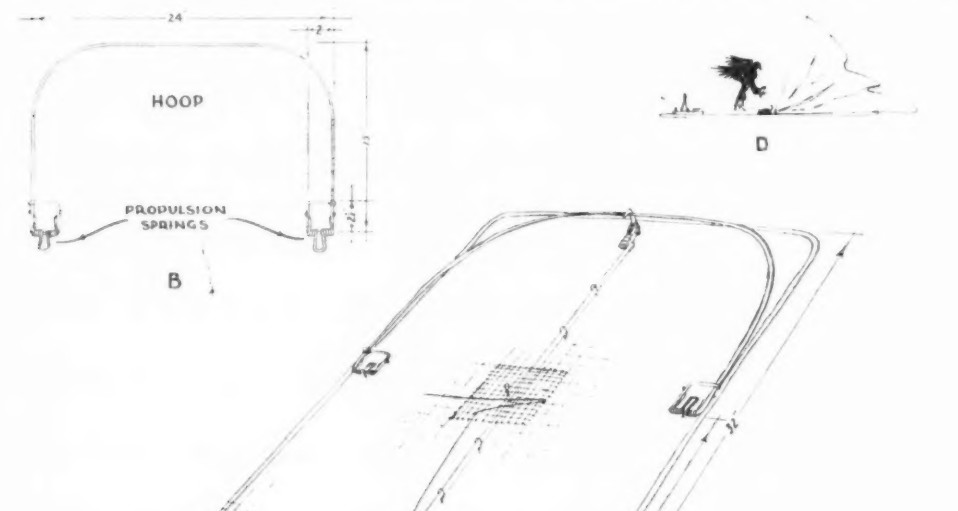

FIG. 1. Details of construction of trap for raptorial birds. A—construction of trigger and latch mechanisms. B—hoop, with propulsion springs. C—sketch of trap set (without net). D—sketch of trap springing.

springs made of a single continuous wire (Victor rat traps are of this type). The ends of the semicircular hoop are bent and fitted to the springs so that the hoop, in effect, replaces the killing bar of the original rat trap. Figure 1,B shows the way in which the hoop is fitted to the springs.

Net.—Although only best-grade cheese cloth and nylon curtain material have been used for the net, minnow seine of 1/4″ or 1/2″ mesh would be more satisfactory for greater strength and durability. The net should be approximately 6′ x 6′ with rounded corners, to allow for ample "bag."

The margins of one-half of the net are sewn to the entire rim of the hoop. The remainder of the net is fastened by the margins to the platform directly under the set position of the hoop. This permits all of the netting to be piled inconspicuously under the hoop when the trap is set. When sprung, the hoop carries forward the leading edge of the net, enclosing the trapped bird between the platform and the net (Fig. 1,D).

Latch.—When set, the net is held open by a simple latch which slides over the middle of the hoop. This latch is fastened to the platform by pieces of strap iron approximately 1/2″ wide and 3/16″ thick. The latch is pierced by a pivot which can be made from a heavy nail. The hoop is released when the latch is snapped off the hoop by a wire which, fastened at one end to the bottom of the latch below the platform, runs through 1/4″ tubing to the trigger mounted near the other end of the platform (Fig. 1,A).

Trigger.—Basically, the trigger is a standard rat trap fastened three inches in from the edge of the platform at the opposite end from the latch. The bait pan of the trap should be of metal so that a thin but stiff wire can be soldered to it. This wire can be bent into a rough T shape and extends approximately nine inches toward the bait at the center of the platform. When the hawk strikes this wire while attacking the bait, the rat trap is sprung. The pull of the rat trap on a bar attached below the platform to the wire running to the latch releases the hoop. Details of this arrangement are given in Figure 1,A.

A simpler trigger and latch can be made as follows: Remove the release bar and bait pan from a rat trap. Fasten the release bar to the platform at the position of the latch in Figure 1A. Mount the bait pan on the platform so that the release bar engages the bait pan as in the original rat trap. When set, the net hoop is held open by the release bar. A stiff trigger wire soldered to the bait pan extends toward the bait. This arrangement eliminates the necessity of making latches, etc., and makes the tubing unnecessary.

Bait platform.—A six-inch square of 1/2″ mesh hardware cloth should be attached at the center of the platform. It can be attached by cutting it one inch oversize and clinching the ends around wires of the main trap platform. This hardware cloth prevents the bait (if a mouse) from crawling down through the platform and out of sight.

Camouflage.—The net should be dyed and the rest of the trap camouflaged with appropriately colored non-glossy paint.

BAIT

In my experience, only living bait has been effective in attracting sparrow hawks, shrikes, and screech owls. I have used laboratory mice (*Mus musculus*) and English sparrows (*Passer domesticus*). In either case, the bait animal is fastened to a wire loop in the center of the platform; sparrows are tethered by means of a soft cotton string tied around one leg, mice by a fisherman's snap swivel or a safety pin passed behind the large tendon above the heel of one hind foot.

Sparrow hawks seldom injure the bait. I have caught as many as six hawks with one mouse.

Sparrows used as bait for sparrow hawks have the advantage of greater visibility than mice. Sparrows seem to me less effective than mice, however, because many sparrow hawks customarily do not feed on birds and will not attack one used as bait. On the other hand, all sparrow hawks regularly feed on mice, especially in winter, and readily enter traps baited with them.

Persons fortunate enough to have access to surplus mice from a laboratory can usually increase their trapping catch by choosing different colored mice for different conditions. For example, I have had good success using black mice when the ground is covered with snow. Conversely, white or other light-colored mice are best on dark ground. In dead grass and

weeds, either very light or very dark mice are equally satisfactory.

OPERATION OF TRAP

For sparrow hawks in winter, I have found that the most effective method is to place a trap either near a perch known to be frequented by a hawk or, even better, to set the trap within view of a perched hawk. Most hawks will not leave if the trap is set from 50 to 150 yards away from them. At this distance they can readily see movements of the bait. An advantage of the latter method is that little time is lost if the hawk leaves without entering the trap. Furthermore, this method exposes the bait to rigorous weather for the least time necessary.

It helps to cover the trap lightly with dead grass, dirt, or snow. However, I have captured many hawks and shrikes in uncovered traps set on bare ground.

In trapping wintering sparrow hawks in Kansas, I have found that I can operate up to four traps efficiently. On migration routes, the maximum number of traps would be governed by the amount of bait and time available.

A measure of the effectiveness of the trap is that in four winter months, in Kansas, I have banded 60 sparrow hawks, although my banding activities have been confined mostly to week-ends. Several birds have repeated in the traps. One female entered one trap, was banded and released, and within five minutes entered another trap set 50 yards away.

This type of trap (in various sizes) has been used to trap such diverse species as long-eared owls (*Asio otus*), great horned owls (*Bubo virginianus*), black-capped chickadees (*Parus atricapillus*), greater prairie chickens (*Tympanuchus cupido*), and starlings (*Sturnus vulgaris*). Shrikes are exceptionally easy to trap with either mice or sparrows. For banders I think this trap could be especially effective in capturing numbers of migrating hawks along flyways and at concentration points.

Accepted for publication February 19, 1953.

FOOD HABITS OF PENNSYLVANIA HOUSE CATS

Thomas Eberhard

Hardy Ranger Station, Moskee Route, Lead, South Dakota

Prior to 1949, very little scientific investigation had been conducted on the feeding habits of vagrant and field-hunting house cats (*Felis catus*) in northeastern United States. Collection of stomachs and feces was begun in April, 1949 and continued until July, 1952, except during an interim of six months in 1950, from May through October. Data obtained from the collection and analysis of 121 stomachs and 12 fecal samples which are included in this report are taken from a thesis by the author, presented in partial fulfillment for the degree of Master of Science, Department of Zoology and Entomology, Pennsylvania State College.

The writer is indebted to Dr. P. F. English for assistance and guidance and to Professor Merrill Wood, for aid in identifying avian remains in food samples. The author is also grateful to those persons who aided in collecting stomachs.

Other surveys of the house cat's feeding behaviour have indicated that songbirds do not form a large part of the animal's diet, which is contrary to common belief. Errington (1936), in Wisconsin, from examination of 50 stomachs by a numerical count method found that 9 birds occurred in comparison to 57 mammals. Nilsson (1940), in Oregon, discovered that 86 cats had ingested 18.6 per cent birds and 61.8 per cent mammals by volume. McMurry and Sperry (1941) found that birds comprised 4 per cent and mammals 55 per cent by volume from examination of 84 cat stomachs in Oklahoma. From analysis of 34 Pennsylvania house cat stomachs, Latham (1950) found one passerine bird and 5 cottontail rabbits in contrast

to 39 other mammals. A record of the catches of a single cat in Michigan was reported by Bradt (1949). This pet, during a period of eighteen months, brought in a total of 1609 rodents and 62 birds, 54 of which were English sparrows. Hubbs (1951) in the Sacramento Valley, California, found that in 184 cat stomachs, birds occurred in 74 and amounted to 25.2 per cent by volume. The majority of these avian remains was of game species, consisting of adult female ring-necked pheasants and adult female ducks. Hubbs' study is the first to show a substantial volume of birds taken by cats, and the only one to reveal ducks as important prey.

With the aid of members of the Pennsylvania Cooperative Wildlife Research Unit and other individuals, the author collected for analysis, 202 cat stomachs and 32 scats. Gathering of motor traffic kills, shooting, and trapping were the means of obtaining specimens. Cats were taken from 22 counties throughout the state, the majority having been collected from Centre, Montgomery, and Bucks Counties. Most specimens were gathered from farm areas, although a lesser number was taken from small towns. Those cats which were recovered or captured in fields were tagged "field," and those animals which were thought to be pets or were taken in towns were tagged "non-field."

There were 121 male cats taken and 81 females, a ratio of 150 males : 100 females. This follows the ratio reported in other studies, which have stated that a higher percentage of males was taken. The average weight of 63 mature males was 8.3 pounds and the average weight of 34 mature females was 6 pounds.

Of the 202 stomachs examined, only 154 contained enough food for comparative analysis. Volumes of foods were measured by water displacement, and results compiled by the gross volume method. Four groups of stomachs are presented: (1) field cats taken during spring and summer (April through September); (2) field cats taken during fall and winter (October through March); (3) non-field cats taken during spring and summer; and (4) non-field cats taken during fall and winter (Table 1). Data obtained from analysis of scats are given in Table 2.

The term "Table Foods and Garbage" used in the food tables includes all varieties of table scraps, milk, offal, string, paper and other refuse ingested as food. "Miscellaneous Animals" include a frog, spiders, and crayfish. The subheading "Mice" is inclusive of native as well as house mice. The term "Songbirds" refers to passerine birds.

Unidentified nestling songbirds were found in 2 field cat stomachs of spring and summer, and complete bodies of juvenile cottontails were recovered from 4 cats taken in spring

TABLE 1.—RESULTS OF ANALYSIS OF 154 CAT STOMACHS

Food Items	Field Cats				Non-field Cats			
	Spring-summer 59 stomachs		Fall-winter 48 stomachs		Spring-summer 22 stomachs		Fall-winter 25 stomachs	
	Frequency of Occurrence	Volume per cent	Frequency of Occurrence	Volume per cent	Frequency of Occurrence	Volume per cent	Frequency of Occurrence	Volume per cent
Rodents	30	31.7	29	30	8	7.9	4	7.6
Mice	25	19	24	23.9	6	3.4	3	3.9
Brown rat	4	12.7	5	6.1			1	3.7
Squirrel	1	tr			2	4.5		
Cottontail	7	12.7	13	23.6	1	.4		
Shrews and moles	7	2.7	1	.3	3	1.4		
Birds	16	18.6	8	6.3	3	2.4	2	2
Songbirds	10	3.8	3	1	3	2.4	1	1.7
Ring-necked Pheasant	1	8.4	1	3.4				
Domestic fowl	5	6.4	4	1.9			1	.3
Insects	17	1.7	4	tr	7	1.3	1	tr
Grass	40	.5	27	.5	15	1.6	6	.5
Table foods and garbage	36	27.9	28	34.7	21	82.	26	86.7
Miscellaneous animals	4	.2			7	3	5	3.2
Unidentified	20	4	19	4.6				

TABLE 2.—FOODS OF FIELD CATS BY ANALYSIS OF 32 FECAL SAMPLES JANUARY THROUGH JUNE

Item	Frequency of Occurrence
UNIDENTIFIED MICE	14
BIRDS	9
Songbird	1
Ring-necked Pheasant	1
Domestic Fowl and Duck	7
COTTONTAIL	6
INSECTS	5
SHREWS	4
OPOSSUM	1
GRASS	21
TABLE FOODS AND GARBAGE	11
UNIDENTIFIED	10

and summer and from one cat killed in October. Some of the adult cottontail and pheasant appeared to be carrion. The domestic fowl and duck were thought to be carrion or parts of carcasses discarded as garbage. During the course of the study, cats were observed eating remains of highway-killed cottontails, domestic fowl, and ring-necked pheasants.

The composition of foods from analysis of scats of field cats follows closely the pattern obtained from analysis of stomach contents.

The comparison between field-hunting cats and those of pet status shows distinct differences. Non-field cats have a diet composed almost entirely of table foods and garbage, while field cats show only 30 per cent of their diet to be composed of these foods. The bulk of the field cat's food consists of wild forms of animals, in contrast to very few wild forms taken by non-field cats. Extremely low occurrence of song-birds and cottontail in the non-field cat's diet gives substantial support to the contention that most well-fed pets will not prey on desirable wildlife forms.

SUMMARY

A total of 202 house cat stomachs and 32 cat fecal samples was collected from April, 1949 through July, 1952. Analyses of stomach contents and feces revealed that rodents, table foods and garbage, and possibly cottontail rabbits were the primary foods of field-hunting cats. Birds, shrews, insects, and other forms were secondary in volume and occurrence. Non-field cats took very few birds and cottontails; their diet consisted mainly of table foods and garbage.

LITERATURE CITED

BRADT, G. W. 1949. Farm cat as a predator. Mich. Cons. **18**: 25–26.

ERRINGTON, P. L. 1936. Notes on food habits of Wisconsin cats. Jour. Mamm. **17**: 64–65.

HUBBS, E. L. 1951. Food habits of feral house cats in the Sacramento Valley. Calif. Fish and Game, **37**: 177–189.

LATHAM, R. 1950. The food of predacious animals in northeastern United States. Final Report, P-R Project 36-R, Pa. Game Comm. (1): 61.

MCMURRY, F. B. and C. C. SPERRY. 1941. Food of feral house cats in Oklahoma. Jour. Mamm. **22**: 185–195.

NILSSON, N. N. 1940. A study of the domestic cat in relation to game birds in the Willamette Valley, Oregon. Master of Arts thesis, Oregon State College, Corvalis.

Accepted for publication April 3, 1953.

COMPARISONS OF SMALL FISH POPULATIONS IN PYMATUNING LAKE, PENNSYLVANIA[1]

F. J. Schwartz and C. A. Tryon, Jr.

Pymatuning Laboratory of Field Biology, Department of Biological Sciences, University of Pittsburgh, Pittsburgh 13, Pa.

During investigations of the productivity of Pymatuning Lake it became desirable to obtain comparisons of relative populations of young fish in two distinct portions of the lake. An experiment, designed to provide data that would permit critical evaluation of any differences between the two areas, was executed during the summer of 1951.

[1] Contribution #3, Pymatuning Laboratory of Field Biology.

Acknowledgments for assistance are due Howard Fox, of the Pennsylvania Fish Commission.

Pymatuning Lake is an impounded body of water lying on the Pennsylvania-Ohio border about thirty-five miles south of Lake Erie. It drains south through the Ohio River system. The lake is divided into three portions by causeways. The upper two of these are known as Sanctuary Lake and Middle Lake and are the two areas compared. They are separated by a dam that keeps the water level of Sanctuary Lake at least two feet higher than that of Middle Lake. This dam is guarded by an electric field that prevents fish movement in either direction. Sanctuary Lake has an area of 2,000 acres and an average depth of five feet; Middle Lake is approximately 7,000 acres and averages twelve feet deep. For a description of the chemical characteristics see Tryon and Jackson (1952).

Collections of small fish were made with traps and seines. Traps were quarter-inch-mesh wire cylinders two feet in diameter and four feet in length. At each end an inverted cone, with an opening of three inches, led into the trap. All traps were permitted to rest on the bottom and in water about six feet deep. This meant that stations were at varying distances from shore.

Ten stations were established in each of Middle and Sanctuary Lakes. Eight traps were set at a station for three consecutive days and then moved to the next station. This procedure was followed in both lakes concurrently from June 16 to July 18. All fish were removed from traps daily. For the first two days at a station, fish were fin-clipped and returned. A different fin clip was used for each trap. On the third day the catch was preserved.

At each station, after trapping was finished, five hauls were made with a ten-foot, quarter-inch-mesh seine. The seining hauls were made as constant as conditions permitted. The fish taken were aged by scale reading or length-frequency graphs. Temperature, barometric pressure, and wind direction were recorded.

The catch records are summarized in Table 1. Only those fish younger than four years are included. Only three species, the yellow perch (*Perca flavescens*), the white crappie (*Pomoxis annularis*), and the bluegill (*Lepomis m. macrochirus*), were caught in sufficient numbers to be suitable for analysis and these are the only species for which the catch record is detailed. The rest, which are lumped together as "others," in Table 1, were the following: common white sucker (*Catostomus c. commersonni*), southern channel catfish (*Ictalurus lacustris punctatus*), northern black bullhead (*Ameiurus*

TABLE 1.—NUMBERS OF FISH TAKEN BY TRAPPING AND SEINING FROM TEN STATIONS LOCATED IN EACH OF THE TWO LAKES

			1	2	3	4	5	6	7	8	9	10	Totals
Seines	Sanctuary Lake	Yellow perch	6	31	20	4	10	24	2	41	25	4	227
		White crappie	19	18	61	106	23	9	2	54	7	1	300
		Bluegill	6	1	4	1	0	0	0	0	0	0	12
		Others	14	1	21	195	30	17	1	13	2	12	306
	Middle Lake	Yellow perch	26	2	1	42	0	13	0	83	6	9	182
		White crappie	1	0	0	0	0	1	1	0	9	0	12
		Bluegill	0	0	0	0	0	0	0	0	0	0	0
		Others	2	5	8	5	3	20	6	16	2	3	70
Traps	Sanctuary Lake	Yellow perch	6	21	27	28	6	11	16	19	17	5	156
		White crappie	3	15	19	67	43	30	169	104	50	30	530
		Bluegill	4	3	0	2	1	3	5	4	5	1	28
		Others	2	3	9	2	4	3	14	9	9	14	67
	Middle Lake	Yellow perch	49	60	33	50	39	30	51	30	18	68	428
		White crappie	0	0	0	0	2	8	17	12	20	24	83
		Bluegill	10	3	3	3	8	3	0	0	1	3	34
		Others	6	8	5	185	9	3	3	2	7	11	239

m. melas), northern brown bullhead (*Ameiurus n. nebulosis*), carp (*Cyprinus carpio*), goldfish (*Carrasius auratus*), bluntnose minnow (*Hyborhynchus notatus*), western blacknose dace (*Rhinichthys atratulus meleagris*), western golden shiner (*Notemigonus crysoleucas auratus*), spotfin shiner (*Notropis spilopterus*), common emerald shiner (*Notropis a. atherinoides*), northern common shiner (*Notropis cornutus frontalis*), largemouth bass (*Micropterus salmoides*), northern smallmouth bass (*Micropterus d. dolomieu*), yellow pikeperch (*Stizostedion v. vitreum*), central Johnny darter (*Etheostoma n. nigrum*), and northern logperch (*Percina caprodes semifasciata*). It is interesting that so many of the species occurring in the lake were taken in these small, unbaited traps.

A total of 2674 young fish were taken in the two lakes; 1565 by traps and 1109 by seining. No significant differences were found associated with temperature or barometric pressure. Wind direction may have produced an effect, but data were insufficient for testing.

In order to test the significance of results, both for the two regions involved and for the methods used, an analysis of variance with multiple classification was used. Procedure followed that outlined by Snedecor (1946). The results of the analysis are as follows: F values in excess of the one per cent level are expressed as highly significant (H), those in excess of the five per cent level as significant (S) and those below the five per cent level are termed not significant (N).

	Yellow Perch	White Crappie	Bluegill
Between lakes.....	N	H	N
Between methods..	N	N	H
Lakes and methods interaction.....	S	N	N

Estimates of total populations have been used extensively in comparing bodies of water; this is of course a logical result of the need for actual population estimates in fisheries biology. The difficulties of obtaining such estimates are well known and have been described in various papers. In most ecological work and considerable management work where comparison of fish populations under different environmental conditions is the objective these difficulties can be by-passed as in the present method.

The present experiment was interesting as all three species caught in sufficient numbers for analysis revealed different aspects of the problem. In the case of the white crappie there was no significant difference between numbers captured by the two methods and there was a significant difference between the two areas sampled. In the bluegill catches no significant differences existed in numbers of young captured from the two areas, but traps caught significantly greater numbers than seine hauls and would appear to be a better method for obtaining samples for this species.

The fact that interaction between methods and areas is significant with yellow perch indicates that selectivity of the two methods for this species is not consistent under the different environments provided by the two areas. While both methods caught considerable numbers of fish, each method would have given a different picture of the relative populations. It would appear that one or the other of the methods is unreliable.

This also means that it is not possible to use these catch records in making percentage composition comparisons between the two areas. This commonly used method is meaningless where selectivity of a capture method is not consistent in the areas being compared.

SUMMARY

In summary the following may be pointed out:

1. A comparison of young fish populations of two different bodies of water was made by two methods—shore seining and hoop nets. The collecting of samples was designed so that catch records could be used in an analysis of variance with multiple classification.

2. One species, the white crappie, occurred in significantly greater numbers in catches from one area. Trap nets caught significantly greater numbers of bluegills than shore seining. The selectivity of the methods was not consistent in the two areas for yellow perch.

3. It would appear valuable to use two or more methods of capture in experiments designed to provide comparisons of catch records between water areas.

LITERATURE CITED

SNEDECOR, G. W. 1946. Statistical methods. Iowa State College Press, Ames.

TRYON, C. A., JR. and D. F. JACKSON. 1952. Summer plankton productivity of Pymatuning Lake, Pennsylvania. Ecology, **33**: 342–350.

Accepted for publication March 26, 1953.